GIS for Risk Areas Analysis of Stolen Motorcycles Crime in COVID-19 Epidemic, Muaeng Chonburi Police Station, Thailand

JUTATIP SUDJAI

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR MASTER DEGREE OF SCIENCE
IN GEOINFORMATICS
FACULTY OF GEOINFORMATICS
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JUTATIP SUDJAI : GIS FOR RISK AREAS ANALYSIS OF STOLEN MOTORCYCLES CRIME IN COVID-19 EPIDEMIC, MUAENG CHONBURI POLICE STATION, THAILAND. ADVISORY COMMITTEE: JIANGUO YAN, NARONG PLEERUX XIANFENG HUANG 2024.

In 2023, Thailand exhibited the greatest motorbike usage rate on a global scale, as reported by the World Atlas website. Specifically, over 87% of Thailand's population resorted to motorcycles as their primary mode of transportation. The Transportation Department of Thailand recorded a total of 22,540,765 registered motorcycles in 2023. Motorcycle enthusiasts in Thailand encounter the pervasive challenge of vehicular theft, alongside the predicaments above. This research focused on the stolen motorcycle crime statistics under the jurisdiction of Mueang Chonburi Police Station, utilizing a dataset spanning five years. The theft rate in 2023 demonstrates a notable upward trend in comparison to the preceding four years. To mitigate motorcycle theft in high-risk areas, it is recommended to employ Geographic Information Systems (GIS) and Photogrammetry approaches to analyze the areas associated with these criminal activities. The concept of crime prevention in areas characterized by high crime rates or elevated risk factors holds the capacity to reduce overall crime levels. This research recommends the implementation of diverse dimension methods that prioritize Crime Prevention through Environmental Design (CPTED) as a means to address this crime and achieve the goal of "Zero Tolerance" in high-risk areas.

The first objective of this study is to conduct crime analysis utilizing GIS-based methods. Using ArcGIS Pro software to analyze the risk areas related to motorbike theft. The risk zones are assessed using Global Moran's I approach of spatial autocorrelation and Getis-Ord Gi* statistics. The Inverse Distance Weight (IDW) method is used to improve the depiction of hot spots. This study aims to compare the results produced using Kernel Density Estimation (KDE) and Ripley's K function to quantify the spatiotemporal signature and identify the scales at which

clustering demonstrates the greatest relevance. Enhancing the understanding of crime-prone environments and facilitating the implementation of Crime Prevention through Environmental Design (CPTED) can be achieved by overlaying police red box checkpoints and land use with risk zones. The results of the three techniques indicate that from 2019 to 2023, Nong Mai Daeng is identified as the highest risk area with varying degrees of confidence: medium (with a 90% confidence level, Gi* = 1.65 - 1.96), high (with a 95% confidence level, Gi* = 1.96-2.58), and very high (with a 99% confidence level, Gi* > 2.56). The land use of Khlong Tamru, which is adjacent to Nong Mai

Daeng, has a significant impact on Nong Mai Daeng. This area is identified as the second highest risk by at least two methodologies annually. The predominant land use in Nong Mai Daeng and Khlong Tamru consists of industrial, village, and city-town-commercial areas. According to crime data from 2019 to 2023, the land use type of village exhibited the highest incidence of motorcycle theft, followed by city-town-commercial and institutional land.

The second objective is to examine the impact of the COVID-19 pandemic by comparing areas of criminal activity that were at risk before, during, and after the epidemic. The findings indicate that Nong Mai Daeng and Khlong Tamru have consistently maintained their status as the most susceptible areas before, during, and after the enforcement of COVID-19 restrictions.

The third objective involves the utilization of Emerging Hot Spot Analysis to examine the temporal and geographical distribution patterns and aggregation characteristics of risk hot spots within a given one-week timeframe and a radius of one kilometer. The results indicate the appearance of new hot spots and sporadic hot spots in Nong Mai Daeng and show new hot spots in Khlong Tamru, which shows resemblances to the Getis-Ord Gi*, IDW, and KDE outcomes. Generate a three-dimensional model through the utilization of drone photogrammetry and Get3D Could to graphically represent new hot spots through the process of Emerging Hot Spot Analysis.

The final aim is to address the issue of motorcycle theft by campaigning for the Thai government to publicly endorse and authorize the adoption of electric

bicycles (e-bikes) as a viable substitute for traditional motorcycles to reduce stolen motorcycle crime in Thailand. The findings of the analysis are highly valuable and significant in providing help to many departments within the Royal Thai Police, particularly about the concept of crime prevention. Police stations can be utilized for operational planning. The allocation of patrollers to the local community. Patrol police must possess a comprehensive understanding of crime hot spots and their physical characteristics before commencing their duties. The presence risk areas of stolen motorcycles pose a potential risk to patrol police during their patrolling duties. In the event of an emergency, which location or road should be utilized? Therefore, GIS and Photo-generated 3D models play a crucial role in the planning and operation of Crime Prevention through Environmental Design (CPTED).

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CHAPTER NO 1: INTRODUCTION

1.1 Background

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 [1]. 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 [2]. A significant number of stolen motorbikes are being transported to the border via Cambodia, Laos, Malaysia, and Myanmar. Following the stolen motorcycle data of Mueang Chonburi Police Station, a total of 367 stolen motorcycle cases were reported during the years 2019 to 2023.

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 related to the current shortage of crime analysis professionals and technologies for crime analysis, such as ArcGIS Pro or Photogrammetry within the Royal Thai Police Department. The potential consequences of this could influence the effectiveness of crime prevention strategies.

Stolen motorcycles have related 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 will be devoid of 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[1] 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 and photogrammetry techniques. The results of risk areas were examined spatial components, including red box checkpoints, as well as land use. Develop a three-dimensional model inside the designated region to evaluate risk areas. An analysis of the possible change in locations with a high risk of stolen vehicle crime in the year before, during, and following the implementation of COVID-19 restrictions and finally, proposing the resolution of motorcycle theft by substituting motorbikes with e-bikes. The findings of this assessment will be employed in study endeavors aimed at benefiting several sectors inside the police station, including patrol police, investigation police, planning police, forensics police, and community policing police.

1.2 Study Area

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 over five years has pertinent details regarding motorcycle theft, including a precise address. 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, namely 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, which is nearly half a million. Chonburi Province is situated in the eastern part of Thailand, specifically at coordinates 13°13′N 101°11′E (WGS - 84 and UTM zone 47). 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.

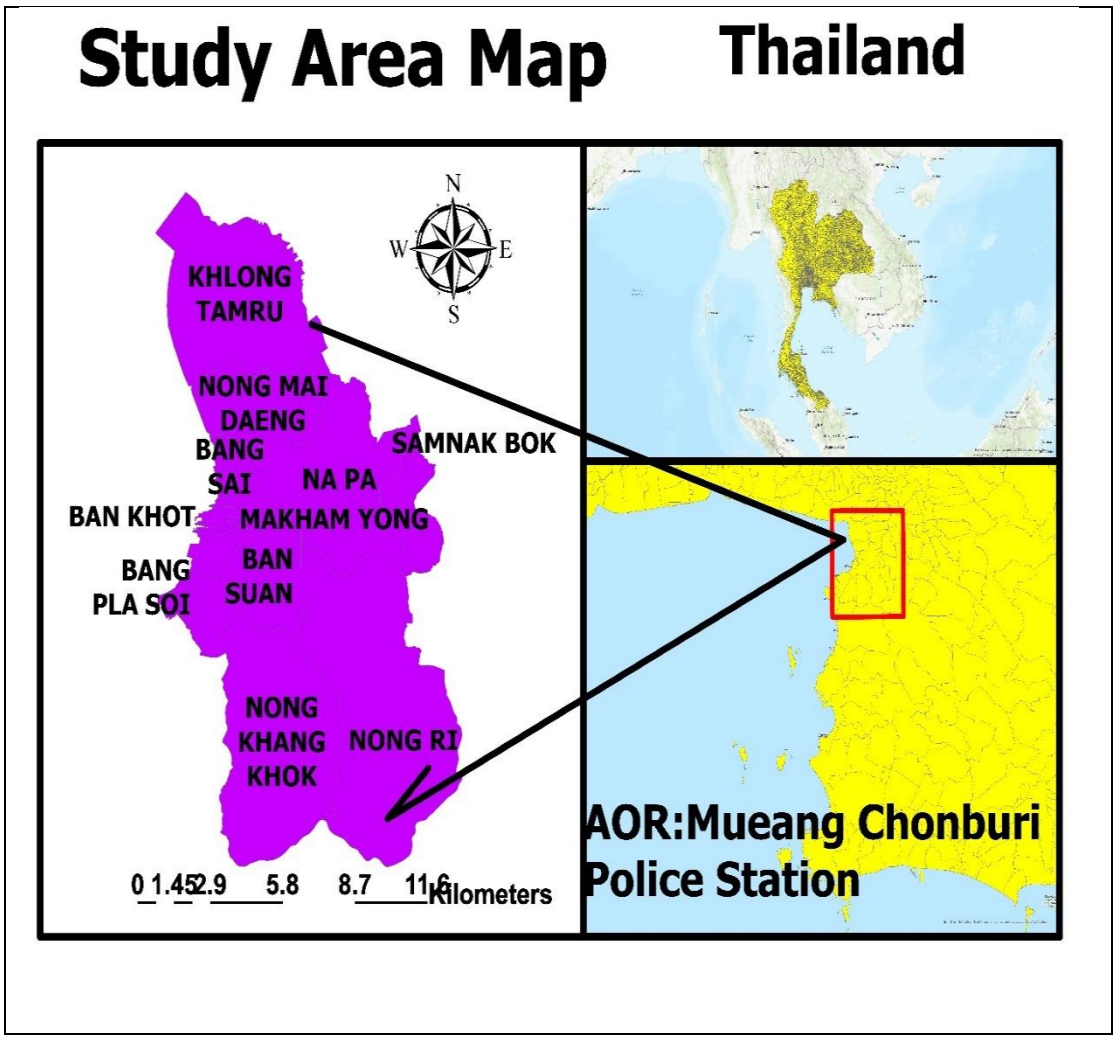


Figure 1: Study area.

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. Chonburi is one of the three Eastern Provinces, alongside Rayong, Chonburi and Chachoengsao that have been official designated by the Thai government as integral components of the Eastern Economic Corridor (EEC). Under the jurisdiction of Provincial Police Region

2 responsible for 8 provinces of the eastern region including Chonburi. The designated jurisdiction encompasses a land area measuring 37,000 square kilometers and is inhabited by approximately 4,283,493 inhabitants. According to the Provincial Police Region 2, the Mueang Chonburi Police Station functions within its authority[3].

1.3 Research Problem

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 related to the current shortage of crime analysis professionals and technologies, such as ArcGIS Pro or Photogrammetry within the Royal Thai Police Department. The potential consequences of this could influence the effectiveness of crime prevention strategies.

1.4 Research Questions

- Do low-risk areas have a higher number of red box checkpoints compared to very high-risk areas?
- What are the similar results between the risk area prediction findings obtained via Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE)?
- Did there be any changes in hot spots and high-risk areas for victimization before, during, and after the COVID-19 pandemic?

1.5 Research Purpose

In recent times, there has been a growing interest among crime researchers and practitioners in exploring the possible advantages of directing crime prevention efforts toward crime occurrence locations. Multiple studies indicate a notable concentration of criminal activity in localized areas, commonly referred to as "hot spots," which account for approximately 50% of all reported criminal incidents. Numerous scholars claim that the reduction of crime can be achieved through the prioritization of hot spot areas by law enforcement personnel. The notion of crime prevention in high-crime or high-risk locations has the potential to decrease overall crime rates. Furthermore, the police force faces constraints in terms of resources, including a relatively small number of officers compared to the population dwelling in the area of responsibility,

as well as budgetary limitations[4]. Therefore, the purpose of this study is to address and prevent crime in specific risk areas that have been identified as hot spots using GIS-based methodologies.

1.6 Objectives

- To analyze the risk areas of motorcycle theft under the jurisdiction of Mueang Chonburi Police Station in Thailand. The study aims to determine the relationship between crime incidents and the use of police red box checkpoints, as well as land use. The results obtained from this research will make a valuable contribution to the advancement of Crime Prevention through Environmental Design (CPTED).
- To compare risk areas of stolen motorcycles under the jurisdiction of Mueang Chonburi Police Station, before, during, and after the onset of the COVID-19 epidemic.
- Creating three-dimensional (3D) models of certain high-risk areas based on Crime Prevention through Environmental Design (CPTED), ensuring accurate identification of incident locations to enhance the operational efficiency of the patrol police, investigation police, forensic and community policing police.
- Promoting the use of e-bikes among motorcycle riders in Thailand as a means to mitigate the issue of stolen motorcycles by learn from China’s experience in adopting e-bikes.

1.7 Research Significance and Contributions

- This study has devised a methodology to evaluate the areas of risk associated with motorbike theft within the jurisdiction of the Mueang Chonburi Police Station in Thailand.
- The objective of this study is to provide support to police stations in their endeavors to prevent and address the issue of motorcycle theft.
- This study provides evidence in favor of the adoption of e-bike user policies in Thailand. The goal is to decrease the incidence of stolen motorcycles and replicate China's effective approaches in safeguarding both assets and

individuals who utilize electric bicycles. It is crucial to prioritize the improvement of riders' safety on the streets.

- The present study offers an examination of the elevated incidence of motorcycle theft, focusing on spatial variables such as red box checkpoints and land utilization.
- This study investigates the risk areas associated with motorcycle theft before, during, and after the COVID-19 pandemic, to proactively address potential unanticipated events in the future.
- This study presents a comprehensive Photo-generated 3D model for identifying high-risk areas, hence providing valuable insights for police strategic and operation planning.

CHAPTER NO 2: LITERATURE REVIEW

This chapter gives a detailed explanation of the various terms and concepts used in the study and related literature.

2.1 Crimes

2.1.1 The Definition of Crimes

Defining a crime encompasses both legal and non-legal dimensions, making it a comprehensive notion. Legally, a crime is defined as the illegal conduct carried out by an individual within a certain country or area. Police within the jurisdictions governed the specific geographic areas and are responsible for safeguarding the lives and property of individuals within such jurisdictions. Crimes involving the perpetration of acts against individuals are commonly referred to as murder or sexual assault. The act of causing harm to the victim's property is commonly referred to as theft and property damage, as well as acts that violate regulations, such as traffic offenses [5].

2.1.2 Type of Crimes

Family matters might be the primary catalyst for an individual's engagement in criminal activities. Some individuals engage in robbery as a means to generate funds for the acquisition of illegal narcotics. Inflicting physical violence on youngsters can significantly contribute to their development of violent behavior in adulthood. There are various types of crimes including Crime against Children, Drug trafficking, Environmental crime/Wildlife crime/Forestry crime, Human trafficking, People smuggling, War crimes/Genocides/Crime against humanity, Corruption, Counterfeit currency and documents, Cultural Heritage crime, Cybercrime/Computer crime, Financial crime/Economic crime/Money laundering, Vehicle Crime, Crime in sport, Firearms trafficking, Illicit goods/, Maritime crime Piracy/Kidnapping/Transnational crime at sea/Terrorism/CBRNE, Organized crime [6].

2.1.3 Cause of Crimes Theories

Right Realism/Rational Choice Theory

Theories of criminal behavior are based more or less on the assumption of rational choice proposed by Beccaria (1995) and Bentham (1843). Bentham wrote that the incentive for criminal behavior is the financial gain derived from the crime, whereas the deterrent effect is the pain caused by the punishment. If the first of these

forces is greater profits, the criminals will commit a crime; if the second, the criminals will not commit a crime [6].

2.1.4 Crime Prevention Theory

Crime Prevention Theories Based on Environmental Approach

CPTED: Crime Prevention Through Environmental Design

According to C. Ray Jeffery, it is important to acknowledge the significance of the physical environment in shaping crime opportunities. The fundamental concept of CPTED is that the constructed surroundings have the potential to either diminish the intensification of crimes, as well as the apprehension of criminal activities. Target hardening is a fundamental tenet of Crime Prevention Through Environmental Design(CPTED). It involves utilizing walls, fences, reinforced doors, windows, and other measures to strengthen buildings, making it extremely challenging and practically impossible for criminals and offenders to gain unauthorized access. According to the proponents of CPTED, the incorporation of these design aspects in community design and planning, as well as the architecture of buildings, explains why certain locations may be more susceptible to specific types of crime, while others may not [7]. Residential and commercial establishments are two distinct categories of premises that are susceptible to vehicle theft. The sites where vehicle thefts occur can be further categorized based on the specific location where the theft took place. These locations include public streets or roadways, parking lots that may be either public or semi-private, as well as carports, garages, and driveways situated on private land [8].

2.2 The Royal Thai Police Structure

The structure of the Royal Thai Police has been divided into 2 major wings：

- The Office attached to the Commissioner General

The Bureaus are as follows: The Office attached to the Commissioner General consists of 15 divisions and 3 Group Positions as follows: Office of the Secretary, Finance Division, Foreign Affairs Division, Personal Division, Budget Division, Police Aviation Division, Traffic and Civil Service Planning Division, Crime Control and Planning Division, Disciplinary Division, Public Relations Division, Welfare Division, Operations Center, Office of Royal Thai Police Policy Making Board,

Office of General Staff and Strategy, Internal Audition Division (Bureau level), International Law Enforcement Academy(ILEA).

- The Bureau consists of 24 bureaus as follows: Immigration Bureau, Metropolitan Police Bureau, Police Region 1-9 (Police Region 2 responsible for all police stations in Eastern provinces of Thailand, including Mueang Chonburi Police Station), Central Investigation Bureau, Narcotics Suppression Bureau, Special Branch, Border Patrol Police Bureau, Office of Legal Affairs, Office of Inspector General, Office of the Royal Court Security Police, Office of Forensic Science, Office of Information Technology and Communication, Police Education Bureau, Police General Hospital, Royal Police Cadet Academy, Office of the Police Commission [9].

Royal Thai Police's Strategic Plan Based on The National Policy

The Royal Thai Police (RTP) is primarily responsible for safeguarding the King and the Royal Family, preventing and combating criminal activities, maintaining public order and security across the Kingdom, and encouraging community involvement in police efforts to prevent and suppress offenses, tailored to the specific needs of each area. The government has enacted a 20-year national strategy and assigned government agencies with the responsibility of formulating their own 20-year strategies to conform to the national development framework and principles. Consequently, the RTP has developed a 20-year strategy for the period of 2018-2037, which consists of four distinct strategies:

Strategy 1: Enhancing the security measures of crucial national establishments and ensuring the safety and stability within the country.

Strategy 2: Enhancing law enforcement capacities, implementing criminal justice, and delivering public services with impartiality and equity.

Strategy 3 involves the involvement of the public sector in upholding social order and sustainability.

Strategy 4 focuses on modernizing the organization and aiming for excellence. The objective is to systematically progress the growth through four consecutive phases, each lasting five years.

Currently, the RTP is responsible for the preparation and maintenance of criminal case statistics, and categorize criminal cases into four types based on the type of offense.

Group 1: encompasses crimes against life, physical integrity, and gender, including murder, sexual assault, attempted murder, physical abuse, rape, and other related offenses.

Group 2: includes a range of property-related offenses, including robbery, extortion, fraud, embezzlement, property loss, receiving stolen objects, ransom kidnapping, as well as motor vehicle and motorcycle theft.

Group 3: cases with special offenses encompass a variety of laws, including the Prevention and Suppression of Trade Act, Child Protection Act, Copyright Act, Patent Act, Trademark Act, Computer Crime Act, Electronic Card Rights (Criminal Code Section 269/1-269/7), Forest Act, National Reserved Forest Act, National Park Act, Wildlife Preservation and Protection Act, Environmental Quality Promotion and Conservation Act 1992, Ivory Act, Land Excavation and Land Filling Act, Customs Act, Prevention and Suppression Act, and Anti-Money Laundering Act 1999.

Group 4: with the state as the victim, consist of drug-related crimes, weapon and explosive offenses, gambling offenses, offenses related to obscene printed materials, Immigration Act violations, offenses related to the prevention and suppression of prostitution, facility service offenses, and alcohol control offenses [10].

Strategic Plan of the Royal Thai Police

1. General Service
2. Criminal Justice
3. Protecting people's lives and properties
4. Traffic Management
5. Human Resource Management

Stolen motorcycle crime is part of the third strategic plan which police officer should pay attention to prevent crime in order to meet the expected accomplishment of RTP.

2.3 The Jurisdiction of Mueang Chonburi Police Station

The jurisdiction of Mueang Chonburi Police Station is around 143.82 km^2 which consists of 11 districts and the population for each area is presented in Table 1. The aggregate population residing within the jurisdiction of Mueang Chonburi Police Station amounts to 435,380 individuals. Ban Suan has the largest population with

65,247 residents, followed by Na Pa with 38,548 residents, and Nong Ri with 15,425 residents. Samnak Bok has the smallest population, consisting of 5,050 individuals.

Table 1: The number of population under the jurisdiction of Mueang Chonburi.

District	Local Population
Nong Mai Daeng	12,333
Khlong Tamru	7,998
Bang Sai	12,269
Bang Pla Soi	15,417
Ban Khot	6,297
Ban Saun	65,247
Makham Yong	6,101
Samnak Bok	5,050
Nong RI	15,425
Na Pa	38,548
Nong Khang Khok	7,833
Total	192,518
Non – Local Population	242,862
Total Population	435,380

Police Station.

Source: Mueang Chonburi Police Station, 2023.

In contrast, the Mueang Chonburi Police Station deployed a total of 274 police officers, as depicted in Figure 2. Therefore, to augment the proficiency of police to deter criminal activity. The utilization of GIS and Photogrammetry techniques is crucial for crime analysis.

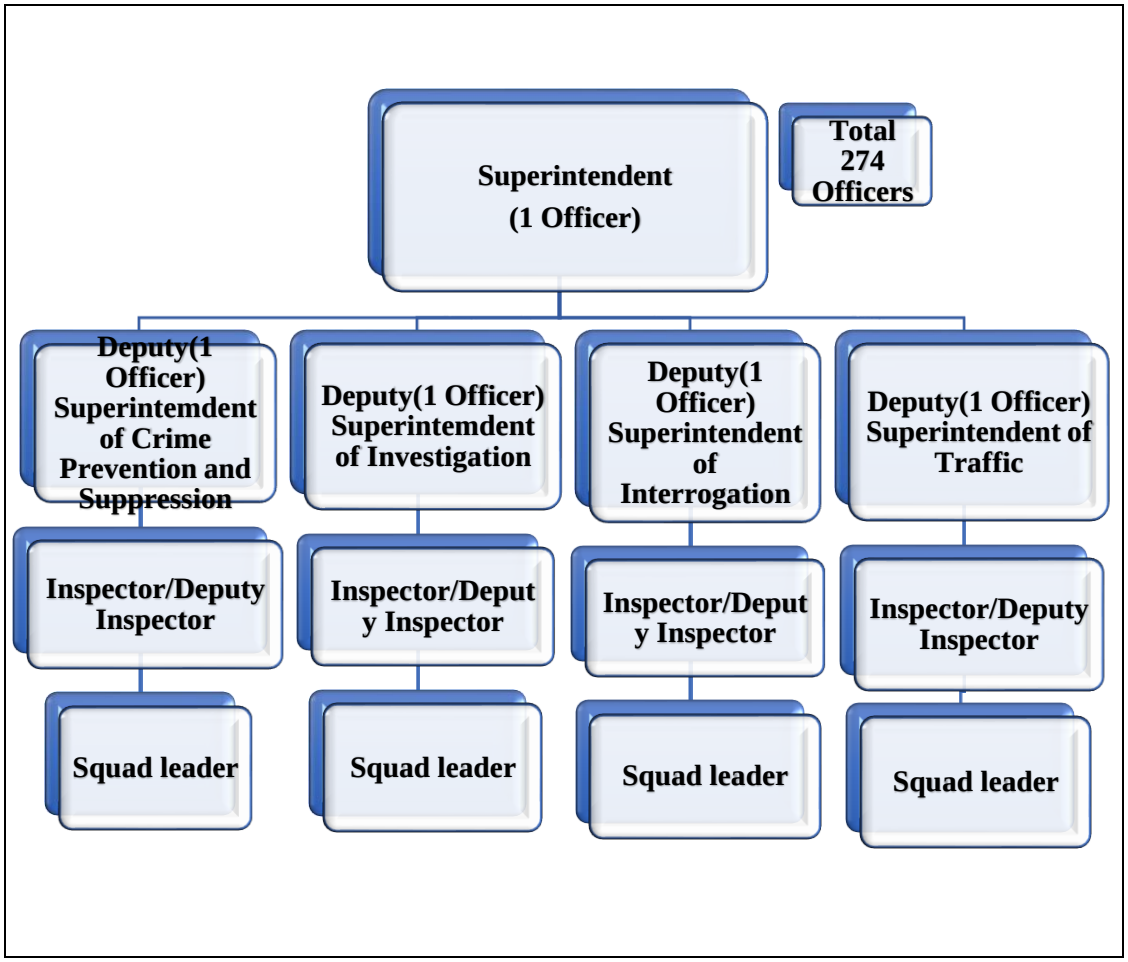


Figure 2: Mueang Chonburi Police Station Structure.
Source: Mueang Chonburi Police Station, 2023.

The tasks of the Mueang Chonburi Police Station encompass five dimensions of the Strategic Plan of the Royal Thai Police.

1. General Service
2. Criminal Justice
3. Protecting people's lives and properties
4. Traffic Management
5. Human Resource Management

According to the third strategic plan of protecting people's lives and properties, the police station must conduct a weekly analysis of offenses. Police

officers conducting patrols while on duty and inspecting police red box checkpoints, as depicted in Figures 3 (a), and 3 (b).

Figure 3: (a) Patrol police while on patrol; (b) Red box checkpoint; Gold shop.
Source: Mueang Chonburi Police Station, 2023.

Patrol police, often referred to as crime prevention and suppression teams, have a vital role in carrying out the third strategic plan. They actively work towards achieving the expected accomplishment specified in the strategic plan. The annual inspection will be conducted by the Police Inspector General to improve job efficiency. Police activities affected the number of crime incidents. In regions with limited police patrolling, there has been a rise in the incidence of criminal activity. According to the key informants, increased police patrol in a specific region reduces the likelihood of criminals engaging in illicit activities [11].

2.4 Stolen Motorcycles Crime Pattern within the Jurisdiction of Mueang Chonburi Police Station

The areas within the jurisdiction of Mueang Chonburi Police Station exhibit various patterns of stolen motorcycle crime, including the trafficking of motorcycles to the border area. Based on the data obtained from the informants, it has been observed that motorcycle theft and trafficking are prevalent inside the border region

of Cambodia. Thailand's Aranyaprathet, Pa Rai, and Ta Kham subdistricts had 81 motorcycle theft instances in 2017, trafficked to Cambodia[12]. The initial pattern exhibited a conventional theft of motorcycles. Motorcycle theft typically follows a pattern where the owner leaves their motorcycles unattended, particularly when the key is still put in the keyhole or when the wheel is unlocked. The incidence shows a higher frequency in the case of motorbikes compared to cars. Motorcycles were highly sought-after and the predominant category of vehicles to be pilfered due to their susceptibility to theft, since thieves could effortlessly transport motorcycles or load them onto trucks. Frequent occurrences of motorcycle disappearances were observed in both private residential areas and public spaces, including marketplaces and department stores. The second observed tendency pertained to instances of motorcycle theft perpetrated by organized crime syndicates. The individuals affiliated with organized criminal organizations would engage in the pursuit and pilferage of motorcycle models as stipulated by the "new motorcycle orders" [13].

2.5 Crime Analysis

Crime analysis is derived from problem-oriented policing, a widely adopted policing approach aimed at identifying crime patterns, resolving criminal incidents, and determining the requisite resources to effectively handle these issues. The utilization of crime analysis is imperative to effectively achieve the objective of problem-oriented policing. Three essential functions that play a significant role in the field of Geographic Information Systems (GIS) and crime mapping are database management, spatial analysis, and data visualization. Crime mapping and geographic information systems (GIS) augment the capacity to comprehend criminal practices. These components can perform overlay functions that integrate the location of crime events with Geographic Information System (GIS) parameters, including land use, regional population, and police red box checkpoints[14]. The analytical methods of GIS used include:

a) Crime mapping involves the presentation of crime locations and timestamps. Statistics typically encompass multiple levels of reference, such as counties, communes, and regions.

b) Hot spots can be identified through the utilization of suitable techniques, enabling the creation of maps that depict the areas with the highest likelihood of criminal activity. These maps also indicate the varying degrees of significance associated with the obtained results. Various methods can be employed to identify these sites, such as utilizing density area cartograms that display location quotients.

c) The statistical method known as spatial autocorrelation can be utilized to detect spatial regions that demonstrate comparable values of a given variable. It also helps assess whether the spatial distribution of a phenomenon is random or if it tends to cluster or disperse. The utilization of spatial autocorrelation is limited to address data exclusively [15].

2.6 Drone Photogrammetry

In the literature, drones are commonly referred to as Unmanned Aerial Vehicles (UAVs). Drones possess a diverse range of capabilities and pricing, encompassing applications in law enforcement, disaster response, delivery services, and entertainment. The utilization of drones has witnessed a notable surge in popularity among both consumers and the research community. The likelihood of drone crimes will surely rise. The number of business shipments in 2020 amounted to 526,000 units, representing a 50% growth compared to the previous year. It is projected that this figure will rise to 1.3 million units by 2023. Unmanned Aerial Vehicles (UAVs) have numerous benefits compared to manned photogrammetry. UAVs are cost-effective and capable of rapidly collecting data. UAV photogrammetry has a lower budget demand than LS equipment[16]. Drone photogrammetry can collect more detailed and useful local landscape information than satellite imagery[17]. In contemporary society, the utilization of satellite remote sensing encounters numerous challenges, including restricted application, exorbitant cost, limited visit ability, and suboptimal resolution resulting from significant altitudes. Alternatively, the Unmanned Aerial Vehicle (UAV) presents itself as a viable alternative[18].

Drone DJI Air 2s

Aircraft

The DJI Air 2S features a new folding design and a fully stabilized 3-axis gimbal camera capable of shooting 4K video and 20 MP photos. DJI signature technologies such as Obstacle Sensing and Intelligent Flight Modes like Active Track 3.0, Point of Interest (POI) 3.0, Quick Shots, and Advanced Pilot Assistance Systems 4.0, make capturing complex shots effortless and easy. The DJI Air 2S boasts a maximum flight speed of 42.5 mph (68.4 kph) and a maximum flight time* of 31 minutes. The image of DJI Air 2S is presented in Figure 4[19].

Figure 4: Drone DJI Air 2S.

2.7 Literature Review

Makrit et al. (2021) undertook a spatial analysis of motorcycle theft crime and made predictions on the occurrence of motorcycle thefts throughout the upcoming five-year period. The study involved the collection of criminal data along the Thai-Cambodian border in three subdistricts inside the Aranyaprathet District of Sa Kaeo Province.

These subdistricts were Aranyaprathet, Pa Rai, and Ta Kham. The Kernel Density Estimation (KDE) method was employed for this purpose[12].

Leigh et al. (2017) employed Kernel Density Estimation (KDE) to address the challenges of hot spot identification and maximum coverage location in the context of placement. This approach aims to enhance police patrolling by reducing reaction times and ensuring accurate identification of incident locations. The police department faces constraints in terms of resources that hinder its ability to enhance the efficiency of public safety. Hence, the strategic arrangement of patrol routes for incident response officers enables the police to effectively deter crime by directing their efforts to the appropriate locations[20].

Ulak et al. (2017) utilized the Kernel Density Estimation (KDE) method to examine the distinct characteristics of crashes related to the factor of aged drivers. Prior studies on traffic safety primarily concentrated on the general population. A GIS-based approach was employed to analyze crash clusters, thereby improving traffic safety [21].

Toppireddy et al. (2018) visualized the area of crime incidents in a 3D model. The realistic 3D interactive image helps navigate the criminal scene. This helps law enforcement assess security. By not visiting the location again, police can determine the reason for the crime and investigate the location [22].

Yue et al. (2017) examined the correlations between three categories of criminal activity and 22 distinct land-use categories in Wuhan, China. The Kernel Density Estimation (KDE) tool in ArcMap 10.2 is utilized for the three forms of crime. The numerical values presented in the legends pertain to the various counts of crime kinds per square kilometer. The findings indicate that over the period from January to August 2013, the districts had a concentration of e-bike theft incidents in the northeastern, eastern, and southern regions. Burglary hot spots were observed in both the northern and southern regions. Instances of robbery tended to cluster in the southern region[23].

Hu et al. (2022) use Kernel Density Estimation (KDE) to analyze the hot spot places of electric bike crashes in Changsha, Hunan Province, China, between daylight and darkness[24].

In Akure, the findings from the GIS Interpolation IDW (Inverse Distance Weight) analysis in Akure indicate a significant prevalence of criminal activities along the primary transportation route that traverses the central area of Akure[25]. The inner core of Odo-Ikoyi exhibits a significantly elevated incidence of crime, while Imuagun Street, the Salvation Army Primary School neighborhood, and Saint David's Anglican church area demonstrate comparatively lower levels of criminal activity.

Saswati et al. (2022) employed Kernel Density Estimation (KDE) and Getis-Ord Gi* to discover and map crime hot spots, with a particular focus on enhancing community safety in metropolitan areas. This study acknowledges that crime is influenced by societal factors such as income and power[26].

He et al. (2021) conducted a study on high-risk locations and hot spots. The system possesses the capability to adaptively modify the level and arrangement of patrol, thereby enhancing the patrol force and frequency in areas or sites with a high risk of attacks. The implementation of an information-led patrol mode is expected to effectively reduce the presence of criminals and mitigate criminal actions, while significantly enhancing the overall efficiency of patrols. In Mainland China, the utilization of GIS in the public security sector is commonly referred to as the "Police Geographic Information System (PGIS)"[27].

Mao et al. (2018) employed a Geographic Information System (GIS) based analysis to ascertain a consistent trend of vehicle theft throughout the Pudong New Area (PNA), a prominent metropolitan region in Shanghai, the largest city in China. Analyzing the spatial and temporal frequencies of vehicle thefts and examining the impact of related environmental factors[28].

Tarhan et al. (2011) extensively utilize crime mapping GIS, which is complemented by 3D environmental models. The advantages of GIS-based crime analysis include operational policing, crime prevention, community engagement, and information sharing, tracking changes in crime distribution over time, and assessing the efficacy of crime prevention measures. Currently, a growing number of municipalities in Turkey are opting to construct or utilize 3D city models[29].

Dewinter et al. (2022) use Global Moran's I, Getis-Ord Gi*, and developing hot spot analysis to effectively allocate limited police resources in terms of spatial and temporal dimensions to implement crime prevention methods on a global scale. This study focuses on analyzing the spatial and temporal distribution of calls for service (CFS) in Antwerp, Belgium, from 2017 to 2020. This study proposes that the allocation of patrol police personnel should be contingent upon the spatial distribution of the CFS per priority code. In the event of peak demand, it is advisable to deploy patrol police in response to the escalating demand[30].

Cheng et al. (2022) demonstrate that crime prevention plays a crucial role in the administration of public security in China. Sichuan Province exhibits a significant prevalence of criminal activities, encompassing property crime, violent crime, gambling, drug-related offenses, and firearms. In this work, a spatio-temporal analysis is employed to examine crime patterns in Sichuan. The findings indicate a lower incidence of crime in the western region and a higher incidence in the eastern region. The spatiotemporal analysis enables the examination of detailed time intervals, such as weekly, daily, or hourly[31].

Osman et al. (2023) use Emerging Hot Spot Analysis to examine a three-dimensional space-time cube representing conflict occurrences in Africa. In the analysis context, space is horizontally mapped and time is vertically mapped. The results indicate the presence of four primary groups of hot spots: new hot spots, consecutive hot spots, sporadic hot spots, and oscillating hot spots [32]

Wu et al. (2023) utilize the Kernel Density Estimation (KDE) approach on street networks in London. The objective of this study is to create an algorithm that utilizes geographic information to identify crime trends at the street level, specifically focusing on areas with high crime rates, commonly referred to as "hot streets". The purpose of this algorithm is to aid the Criminal Investigation Department (CID) in effectively monitoring changes in crime and capturing criminals in a timely manner. The law enforcement tactic known as "Hot spots policing" has proven to be efficacious in addressing criminal activities. Given the challenges of rising crime rates and limited police resources, it is crucial for police patrols in cities to focus their efforts on specific geographic areas with precision, rather than relying on general "hot spot" areas. The algorithm was discovered to be capable of generating "hot street" maps for Law Enforcement Agencies (LEAs), facilitating more efficient allocation of police patrolling [33].

Pribadi et al. (2021) represent the distribution of verified COVID-19 cases and identify areas with a high risk of transmission. Additionally, the aim is to analyze the underlying spatial processes that contribute to the patterns of COVID-19 cases in Jakarta, Indonesia. The investigation utilized Emerging Hot Spot Analysis and space-time scan statistics to examine the dynamics of infected cases and the risk of transmission. The findings indicate that spatial transmission persists, even while the overall pandemic curve declines during the implementation of LSSR. The observed phenomenon is most likely influenced by the sorts of communities, the distribution of population density, and the transportation networks [34].

The importance of police work lies in its role in crime prevention. There is a plethora of research studies focused on crime prevention, with a particular emphasis on the role of patrol police. Hot spot analysis and photogrammetry can improve the effectiveness of law enforcement in crime prevention and support the police in achieving the goals outlined in the strategic plan, which is based on national policy.

CHAPTER NO 3: MATERIALS AND METHODS

3.1 Data Collection

3.1.1 Stolen Motorcycles Crime Data

This study aims to examine the occurrences of motorbike theft as reported by victims at Mueang Chonburi Police Station. 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.

3.1.2 UAV Imagery

A low-cost UAV (DJI AIR 2s) was used to capture the images of a small section of risk areas with no GCP (direct georeferencing; using only UAV onboard sensor information without RTK/PPK solutions). This indirect approach is recommended for accurate georeferencing when low-cost UAV-based photogrammetry is performed without RTK/PPK solutions. The DJI AIR 2s features master shot systems, and it captures complex shots using signature DJI technologies. The UAV camera lens has a focal length of 35 mm and a sensor of 20 megapixels (1” CMOS). The DJI AIR 2s is equipped with an in-built Global Navigation Satellite System (GPS and GLONASS) with a hovering accuracy range; vertical: ± 0.1 m (when vision positioning is active), ±0.5 m (with GPS positioning) and horizontal: ± 0.3 m (when vision positioning is active) and ±1.5 m (with GPS positioning). The in-built GNSS allows the UAV to capture geolocated images, which helps to reduce processing time. To produce a model with good accuracy, the UAV survey must have multiple viewpoints, and adequate overlap (85% front overlap and 85% side overlap.

The flight path was designed in such a way that it slightly extends beyond the boundary of the study site to ensure full coverage. The UAV home point was set approximately at the start of the flight path and a flying height of 80 m was set. The UAV flew covering 4 risk areas, R1 of 0.016 square kilometers, R2 of 0.016 square kilometers, R3 of 0.0016 square kilometers, and R4 of 0.0032 square kilometers[35]. The flight planning for the DJI AIR 2s to take photographs of high-risk areas is presented in Table 2.

Table 2: Flight planning for 4 risk areas.

Risk Areas	Location	Participants	Date
R1	Bus station, Nong Mai Deang	4 (1 pilot, 2 patrol police officers, 1 researcher)	13/2/2024
R2	Ninja market, Nong Mai Deang	4 (1 pilot, 2 patrol police officers, 1 researcher)	13/2/2024
R3	Room for rent (un named), Khlong Tamru	4 (1 pilot, 2 patrol police officers, 1 researcher	13/2/2024
R4	Panee Room for Rent, Khlong Tamru	4 (1 pilot, 2 patrol police officers, 1 researcher	13/2/2024

There are 2 main parts to successful data collection for drone mapping: Planning and Flight. Use Map Pilot Pro for flight as the following process:

PLANNING

1. Plan for the study area. Open the Altitude Adjustment pull-out menu to check the current altitude flight will be planned for.

2. Place Boundary Markers by tapping and holding the locations that are the study area.

3. Open the Map Control pull-out menu to save the mission. Press the Save button on the left to save the mission for offline use or to repeat it.

Map Pilot Pro was utilized to assess four risk areas, namely R1: Bus station, Nong Mai Deang, R2: Ninja market, Nong Mai Deang, R3: Room for rent (unnamed), Khlong Tamru, R4: Panee room for rent, and Khlong Tamru. The corresponding risk zones are depicted in Figures. 5, 6, 7, and 8.

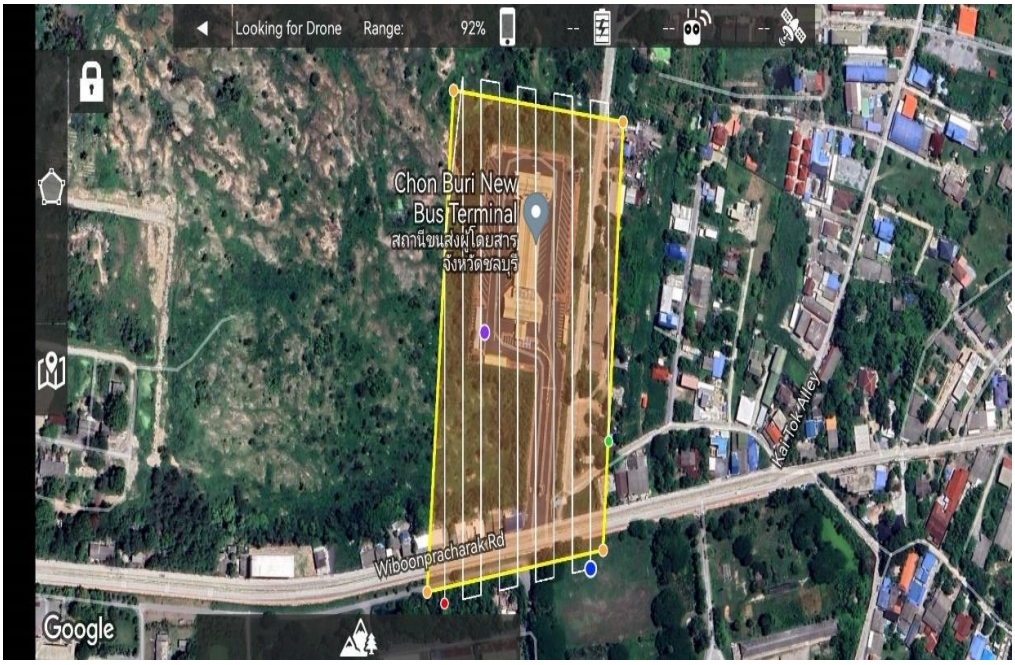


Figure 5: Map Pilot Pro flight for risk area: R1 Bus station, Nong Mai Daeng.

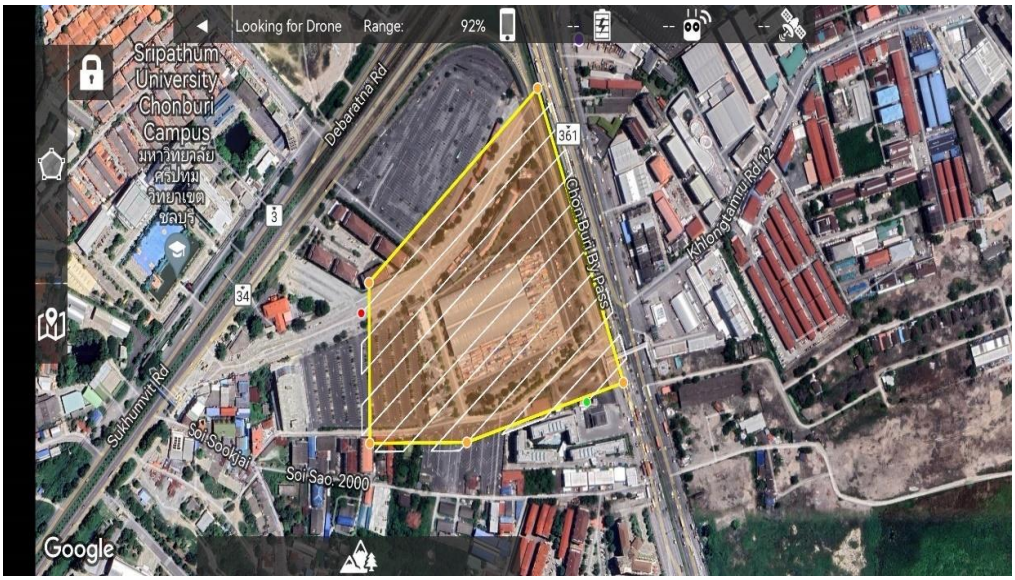


Figure 6: Map Pilot Pro flight for risk area: R2 Ninja market, Nong Mai Daeng.

Figure 7: Map Pilot Pro flight for risk area: R3 room for rent (unnamed), Khlong Tamru.

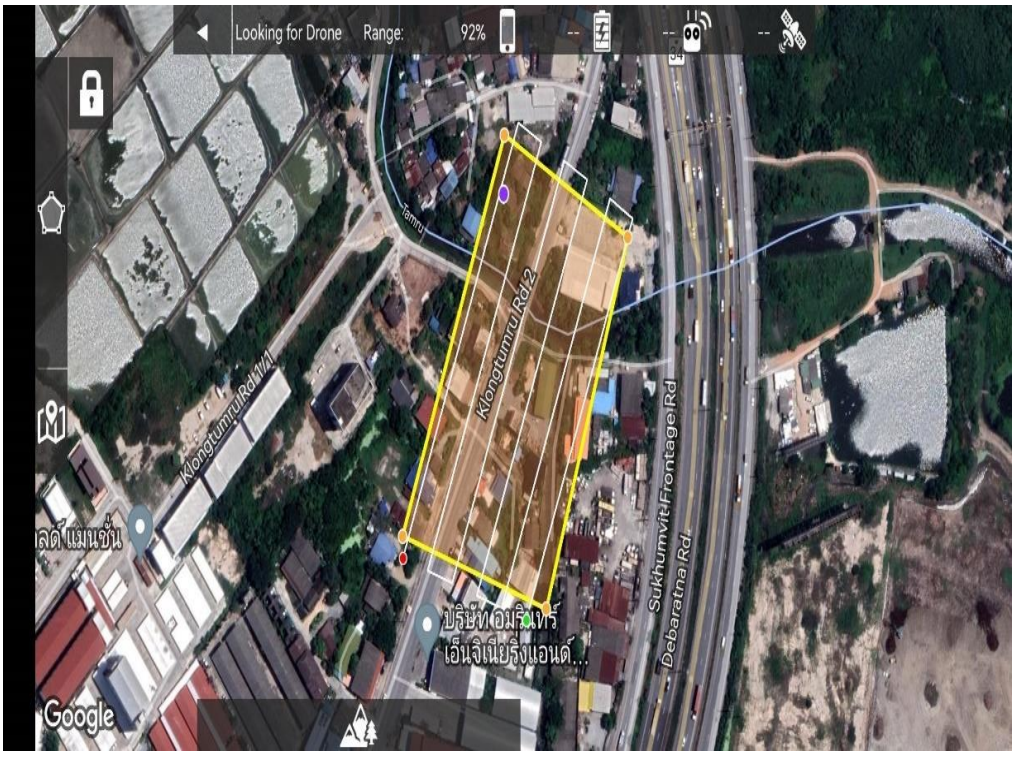


Figure 8: Map Pilot Pro flight for risk area: R4 Panee room for rent, Khlong Tamru.

FLIGHT

1. Open the Flight Control pull-out menu and push the Upload button. This will execute a pre-flight check to make sure the system is ready to collect data. The mission will be automatically uploaded to the aircraft.
2. Press the Start button. The aircraft will automatically ascend vertically to the cruising altitude and set the gimbal to nadir (straight down).
3. The aircraft will automatically navigate along the flight path taking images at appropriate intervals.
4. Once the mission is complete, the aircraft will automatically proceed to the point above the Home Point and the mission is complete.

3.2 Data Analysis

3.2.1 Risk Areas Analysis

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[36].

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[37].

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* can be written as:

$$\text{Gi*(d)}=\frac{\Sigma_j W_{ij}(d)xj-W_i^*\bar{x}^*}{S^*\{[(nS^*1_i)-W_i^{*2}]/(n-1)\}^{1/2}} \qquad (1)$$

where 'W_{ij} (d)' is a spatial weight vector with values for all cells '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[38].

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 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 given by:

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

$$v_k(x) = \frac{w_k(x)}{\Sigma_{i=n}^{n} w_i(x)} \qquad (2)$$

for x/∈ $\{x_1, \ldots, x_n\}$ and $v_k(x_i) = 1$ if i = k and 0 otherwise. Thus, by definition, $\hat{y}$ interpolates the data. The weighting function $w_k(x)$ is chosen so that the prediction at x is influenced more by the nearby points than the distant points[25].

Global Spatial Autocorrelation: Global Moran's I

The Spatial Autocorrelation (Moran's I method), works not only on feature locations or attribute values alone but on both feature locations and feature values simultaneously. Given a set of features and an associated attribute, it evaluates

whether the pattern expressed is clustered, dispersed, or random. Moran's I is one of the oldest indicators of global spatial autocorrelation and is still used for determining spatial autocorrelation. It compares the value of the variable at any one location with the value at all other locations and can be represented as:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1 j\neq i}^{n} W_{ij\cdot}(x_i-\bar{x})(x_j-\bar{x})}{s_0\Sigma_{i=1}^{n}(x_i-\bar{x})^2} \forall i = 1,\ldots..,n\hat{}\forall j = 1,\ldots,n \quad (3)$$

where x_i is the value of the feature on location i, x is the feature mean, n is equal to the total number of locations, W_{ij} is the spatial weight representing connectivity relationships 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 among the features, an attribute is randomly distributed in the study area. The statistical significance of this test is calculated from the Z score assuming normal distribution with mean and variance equal to zero and one respectively. A positive Z score implies that the feature is surrounded by similar values. A negative Z score shows that the neighboring features have different values[38].

Kernel Density Estimation (KDE)

Kernel Density Estimation (KDE) is an algorithm that converts discrete data points into a probability distribution[39]. Kernel Density Estimation (KDE) analysis is a spatial analysis method that is different from traditional point density estimation methods and has higher continuity estimation results. It can estimate the unknown density based on the distribution characteristics of the research object and can display the spatial distribution in a grid. The height of the kernel density value represents the degree of spatial aggregation of the research object calculated as follows:

$$F_n(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x-x_i}{h}\right) \quad (4)$$

In the formula: $F_n(x)$ is the estimated value of density, h is the search radius, k is the kernel density function, n is the sample size of the complaint points, and $(x - x_i)$ is the two complaints' estimated distance between points[40].

Ripley's K function

To characterize the spatial distribution patterns of historical stolen motorcycle point events, Ripley's K function was used as it determines the events that show a statistically significant spatial clustering or dispersion by cumulating the distributional frequency of the distances among the events with the changing of neighborhood size. Commonly, Ripley's K function is transformed as a linear L function for facile interpretation. The L function is implemented as follows:

$$L(d) = \sqrt{\frac{A\Sigma_{i=1}^{n}\Sigma_{j=1 j\neq i}^{n} K(i,j)}{\pi n(n-1)}} \quad (5)$$

where d is the distance, n is equal to the total number of point events, A is the total area, ki,j is a weight, which (if there is no boundary correction) is 1 when the distance between i and j is less than or equal to d and 0 when the distance between i and j is greater than d. The output of Ripley's K tool includes the values of ExpectedK, ObservedK, DiffK, LwconfEnv, and HiconfEnv. The ObservedK value refers to the actual density of points in different distances, and the ExpectedK value refers to the expected distribution in the case of random distribution. LwConfEnv and HiConfEnv contain confidence interval information for each iteration of the tool. If the ObservedK of the specific distance is greater than the ExpectedK, the distribution is more clustering than that of the random distribution. If the ObservedK is less than the ExpectedK, the dispersion of the distribution is higher than that of the random distribution. If the ObservedK is greater than the HiConfEnv, the spatial cluster characteristic for the distance is statistically significant. If the ObservedK is less than LwConfEnv, the spatial dispersion characteristic for the distance is statistically significant. The DiffK contains the difference between the ObservedK and the ExpectedK. The maximum DiffK will determine the most obvious distance where the spatial clustering process is most pronounced[41].

Emerging Hotspot Analysis

Getis-Ord Gi* hot spot analysis and Kernel Density Estimation (KDE) analysis show patterns of crime density but lack the temporal characteristics of these stolen motorcycles. Therefore, space-time cube (STC) analysis was used for spatiotemporal analysis of stolen motorcycles. Emerging Hotspot Analysis in Time

and Space, Torsten first proposed the space-time cube model in 1970, to establish a three-dimensional coordinate the x and y axes represent the position of the feature, and the t axis represents the time when the feature occurs, which used to describe the change process of the geographic feature with the change of time and space. Later, with the development of the space-time model method, based on the combination of the Getis-Ord Gi* hot spot analysis and Mann-Kendall trend test method, EHAM based on the space-time cube the model was proposed to identify cold/hot spots. The pattern and trend of changes in time and space. To put it simply, it can be seen as extending the original spatial definition of the traditional Getis-Ord Gi* hot spot analysis to the space-time definition. The expanded calculation formula is as follows:

$$\mathrm{Gi} = \frac{\sum_{j=1}^{n} \omega_{ij} x_j - \sum_{j=1}^{n} \omega_{ij}}{S \sqrt{\left[n(n-1) \sum_{j=1}^{n} \omega_{ij}^2 - 1 \right] \Big/ (n-1)\left(\sum_{j=1}^{n} W_{ij}\right)^2}}$$

$$\bar{X} = \frac{1}{n} \sum_{j=1}^{n} x_j$$

$$\mathrm{S} = \sqrt{\frac{1}{n} \sum_{j=1}^{n} x_j^2 - (\bar{X})^2} \qquad (6)$$

Where: Gi is the value of z, which is the statistical indicator of cold and hot spots; x_j is the attribute value of the space-time cube j. If j falls within the domain space range and domain time range of the target cube I at the same time, then ω_{ij} ¼ 1, If not, then ω_{ij}¼ 0; n is the total number of space-time cubes; X and S are the mean and standard deviation of the attribute values of all space-time cubes. EHA can be realized with the help of ArcGIS Pro [40]. Before it is possible to run this tool on the data set, a space-time cube is created by aggregating the incident points. To create these space-time cubes, with a diameter of 1 km and time in 1 week. Data can be visualized in three dimensions: the x and y dimensions represent space and a third axis represents time as presented in Figure 9. These bins are associated with the same time-step interval. Subsequently, this space-time cube is used by the Emerging Hot Spot analysis tool to identify hot spots in space and time [30]. The Emerging Hot Spot Analysis tool categorizes each study area location as shown in Table 3.

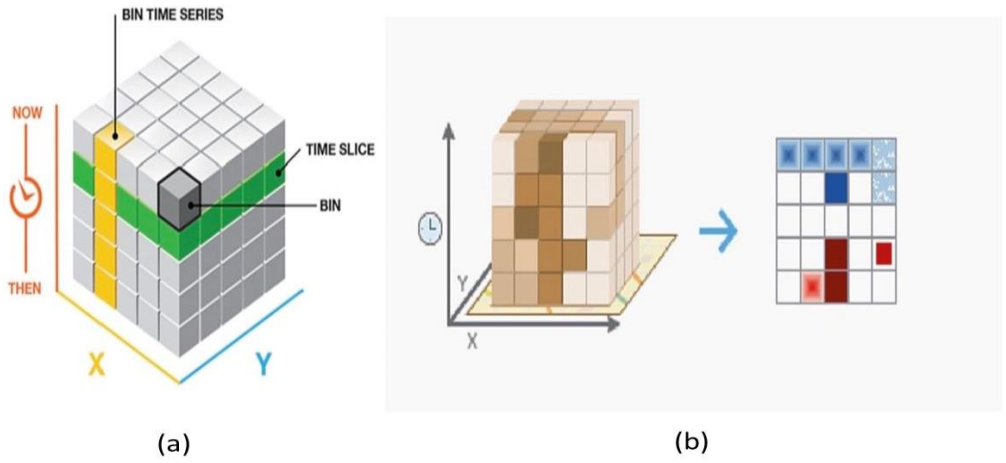
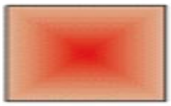
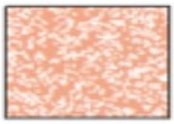
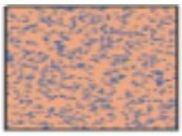
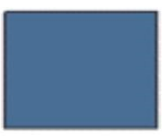


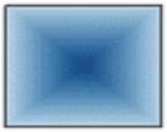
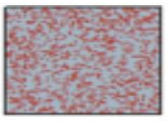
Figure 9: (a) Structure of STC in 3D (b) Generated bins in 2D by running emerging hot spot.

The Emerging Hot Spot Analysis tool identifies trends in data, such as new, intensifying, diminishing, and sporadic hot and cold spots. Based on the z-score and p-value of the generated trend for each location containing data, and the hot z-score and p-value of each cube, 17 spatiotemporal evolution modes can be derived[40].

Table 3: Emerging Hot Spot Analysis tool categorizes each study area location.

	Pattern name	Definition
	No Pattern Detected	Does not fall into any of the hot or cold spot patterns defined below.
	New Hot Spot	A location that is a statistically significant hot spot for the final time step and has never been a statistically significant hot spot before.
	Consecutive Hot Spot	A location with a single uninterrupted run of at least two statistically significant hot spot bins in the final time-step intervals. The location has never been a statistically significant hot spot prior to the final hot spot run and less than 90 percent of all bins are statistically significant hot spots.

	**Intensifying Hot Spot**	A location that has been a statistically significant hot spot for 90 percent of the time-step intervals, including the final time step. In addition, the intensity of clustering of high counts in each time step is increasing overall and that increase is statistically significant.
	**Persistent Hot Spot**	A location that has been a statistically significant hot spot for 90 percent of the time-step intervals with no discernible trend in the intensity of clustering over time.
	**Diminishing Hot Spot**	A location that has been a statistically significant hot spot for 90 percent of the time-step intervals, including the final time step. In addition, the intensity of clustering in each time step is decreasing overall and that decrease is statistically significant.
	**Sporadic Hot Spot**	A statistically significant hot spot for the final time-step interval with a history of also being an on-again and off-again hot spot. Less than 90 percent of the time-step intervals have been statistically significant hot spots and none of the time-step intervals have been statistically significant cold spots.
	**Oscillating Hot Spot**	A statistically significant hot spot for the final time-step interval that has a history of also being a statistically significant cold spot during a prior time step. Less than 90 percent of the time-step intervals have been statistically significant hot spots.
	**Historical Hot Spot**	The most recent period is not hot, but at least 90 percent of the time-step intervals have been statistically significant hot spots.
	**New Cold Spot**	A location that is a statistically significant cold spot for the final time step and has never been a statistically significant cold spot before.
	**Consecutive Cold Spot**	A location with a single uninterrupted run of at least two statistically significant cold spot bins in the final time-step intervals. The location has never been a statistically significant cold spot before the final cold spot run and less than 90 percent of all bins are statistically significant cold spots.

	**Intensifying Cold Spot**	A location that has been a statistically significant cold spot for 90 percent of the time-step intervals, including the final time step. In addition, the intensity of clustering of low counts in each time step is increasing overall and that increase is statistically significant.
	**Persistent Cold Spot**	A location that has been a statistically significant cold spot for 90 percent of the time-step intervals with no discernible trend in the intensity of clustering of counts over time.
	**Diminishing Cold Spot**	A location that has been a statistically significant cold spot for 90 percent of the time-step intervals, including the final time step. In addition, the intensity of clustering of low counts in each time step is decreasing overall and that decrease is statistically significant.
	**Sporadic Cold Spot**	A statistically significant cold spot for the final time-step interval with a history of also being an on-again and off-again cold spot. Less than 90 percent of the time-step intervals have been statistically significant cold spots and none of the time-step intervals have been statistically significant hot spots.
	**Oscillating Cold Spot**	A statistically significant cold spot for the final time-step interval that has a history of also being a statistically significant hot spot during a prior time step. Less than 90 percent of the time-step intervals have been statistically significant cold spots.
	**Historical Cold Spot**	The most recent period is not cold, but at least 90 percent of the time-step intervals have been statistically significant cold spots.

Source:ArcGIS Pro, 2023.

3.2.2 Analyzing Risk Areas with GIS Factors

408 Police Red Box Checkpoints in the Study Area

Additionally, the research focuses on the analysis of risk areas using GIS factors. Examine the correlation between the 408 police red box checkpoints and locations of high-risk for stolen

motorcycles. The 408 police red box checkpoints and their corresponding locations are depicted in Figures 10 (a), and 10 (b).

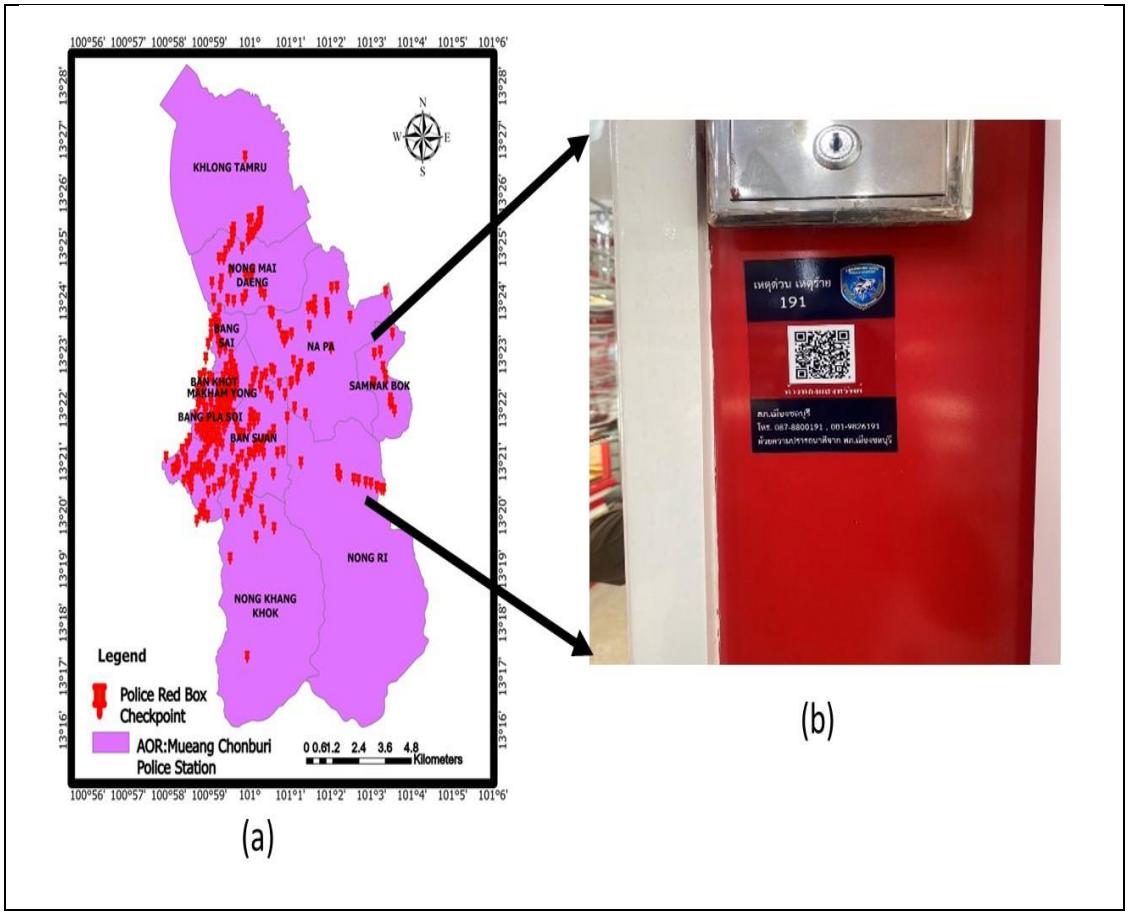


Figure 10: (a) 408 police red box checkpoints in AOR of Mueang Chonburi Police Station; (b) Red box checkpoint.

Source: Mueang Chonburi Police Station, 2023

The Mueang Chonburi Police Station uses red box checkpoints as a patrol strategy to mitigate criminal activities. Patrol officers will scan the QR code of the red box checkpoints, and thereafter communicate the resulting report to the Thailand Police 4.0 application system in a prompt manner. The patrol crew functions in three distinct shifts, from 00.01 to 08.00 hours, from 08.01 to 16.00 hours, and from 16.01 to 00.00 hours. Each shift must visit the red box checkpoints twice within 8 hours.

Land Uses Mueang Chonburi City

This study aims to investigate the relationship between incidences of stolen motorcycle crime and land use under the jurisdiction of Mueang Chonburi Police Station, located in Mueang Chonburi City, Thailand. The focus of this study is to

identify the areas that exhibit the greatest risk of occurrences by employing hot spot analysis using ArcGIS Pro. Overlay the hot spot results with land use. The land utilization of Mueang Chonburi City is seen in Figure 11.

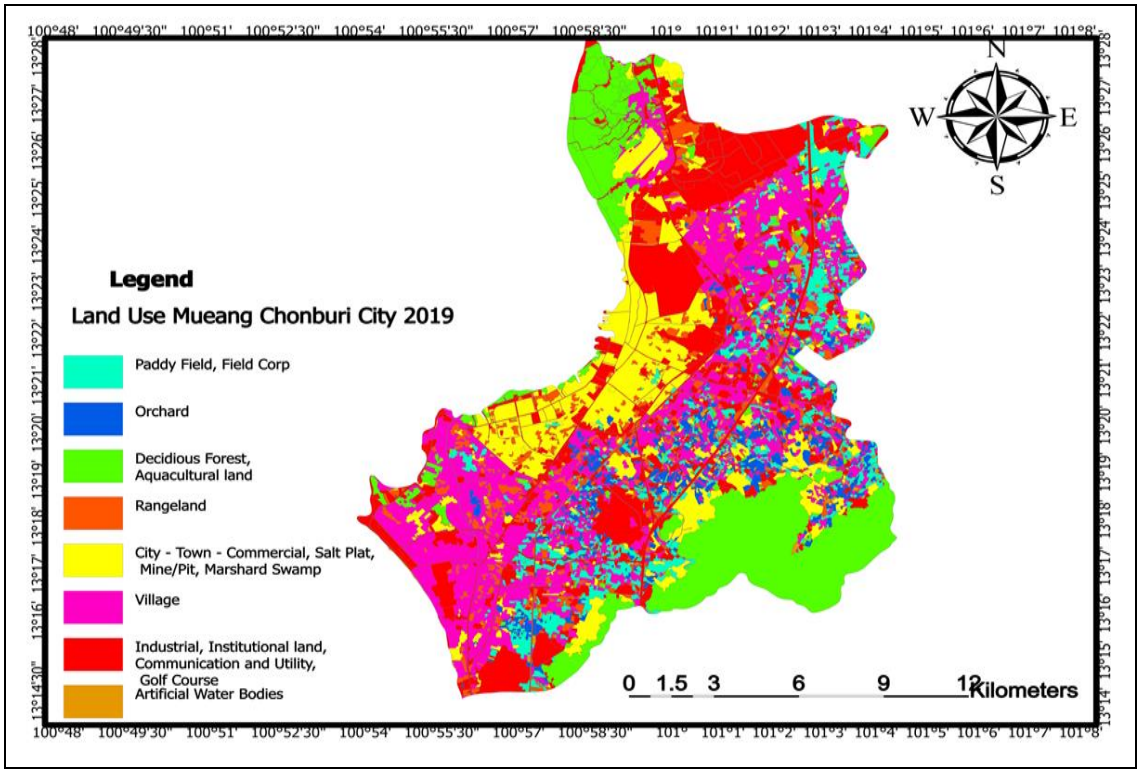


Figure 11: Land Use Mueang Chonburi City, Chonburi Province, Thailand.

Source: Department of Lands , 2019.

Mueang Chonburi City encompasses a diverse range of land uses, including paddy fields, field corp, orchards, deciduous forests, aquacultural land, rangeland, city-town-commercial areas, salt plat, mine/pits, marshard swamps, village, industrial areas, institutional land, communication and utility facilities, golf courses, and artificial water bodies. Table 4 illustrates the land use category that receives the highest level of attention from the Mueang Chonburi Police Station. The land use categories in the vicinity of Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong primarily consist of city-town commercial activities, particularly gold merchants, which require regular inspection by patrol police. Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong collectively encompass over 50 gold shops. Many gold businesses are equipped with police red box checkpoints as a means of ensuring security.

Table 4: Land use under the jurisdiction of Mueang Chonburi Police Station.

Land use	Total	Land use	Total
Bank	52	Pawn shop	4
Gold shop	50	Antique shop	308
7-11	88	University	1
Fuel station	33	School	67
Gas station	12	Hospital	9
Department store	4	Institutional	44
Factory	115	Post office	2
Market	8	Temple	43
Mosque	1	Church	3
Shrine	14		

Source:Mueang Chonburi Police Station, 2023.

3.2.3 Comparing Stolen Motorcycles Crime Risk Areas Before COVID-19, During and Post COVID-19 Timeframe.

The World Health Organization (WHO) has declared coronavirus disease 2019 (COVID-19) to be a public health emergency of international concern (World Health

Organization (WHO) in the fight against COVID-19, Geographic Information Systems (GIS) and big data technologies have played a vital role in several aspects, such as rapid visualization of pandemic information [42]. Moreover, Geographic Information Systems (GIS) was used to analyze various types of crime that happened in this timeframe. The COVID-19 pandemic has changed the way humans travel, possibly creating a permanent shift in travel volume, frequency, and destination [43]. Many countries have implemented mobility restriction measures, and some have been successful at reducing the number of COVID-19 cases [44].

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. Therefore, the present study aims to conduct a comparative analysis of hot spots and high-risk areas associated with stolen motorcycle crime during the pre-COVID-19, COVID-19 timeframe, and post-COVID-19 periods[45]. Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) methodologies were used to analyze risk areas in the period of 2019-2023.

3.2.4 Generate 3D Model in the Risk Areas

A three-dimensional model of risk zones generated by the use of photographs. R1: Bus Station (Nong Mai Daeng), R2: Ninja market (Nong Mai Daeng), R3: Room for rent (unnamed, Khlong Tamru), R4: Panee room for rent (Khlong Tamru) provided by Get3D Cloud created by DASPATIAL company is depicted in Figure 12. Using the Get3D Cloud to compute image positions with links between matched photos. Get3D Cloud, along with the corresponding risk areas R1, R2, R3, and R4 as shown in Figures 13, 14, 15, and 16. The integration of spatial analysis and 3D models provides novel insights into the identification and comprehension of areas with high rates of stolen motorcycle crimes. This information will greatly assist the decision-making process of the higher command at the Royal Thai Police Head Office in Bangkok, eliminating the need for on-site visits. They have the ability to make a choice within their office and review the report from the police station or other departments.

Figure 12: Get3D Cloud.

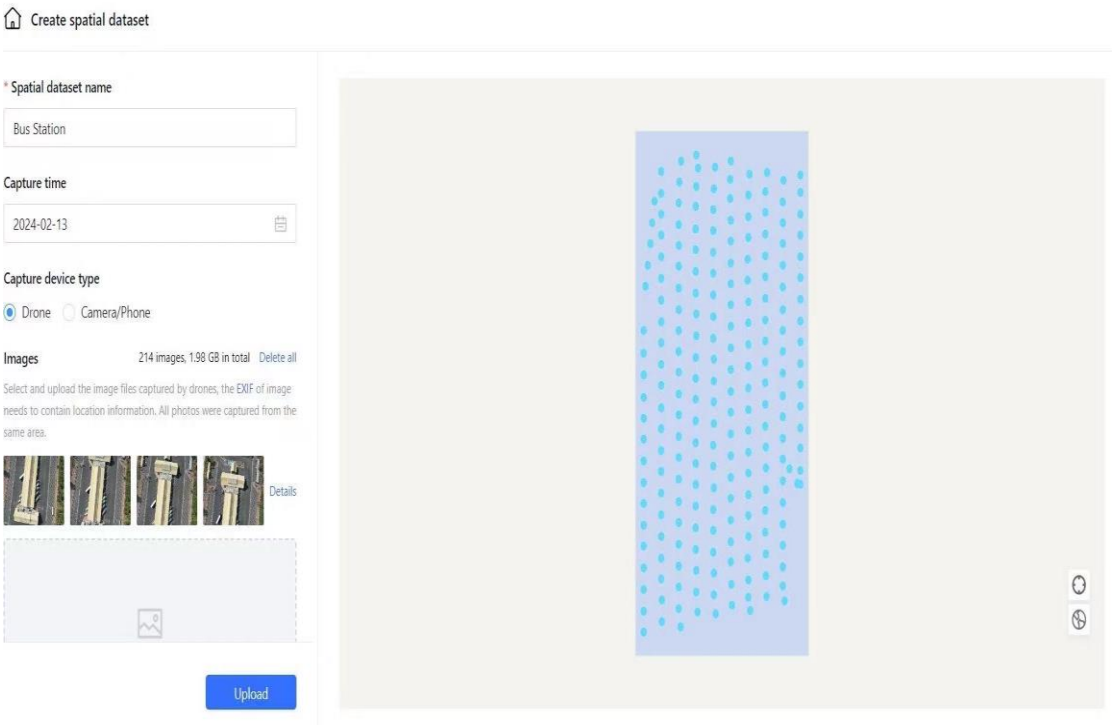


Figure 13: The computed image positions by Get3D Cloud: R1.

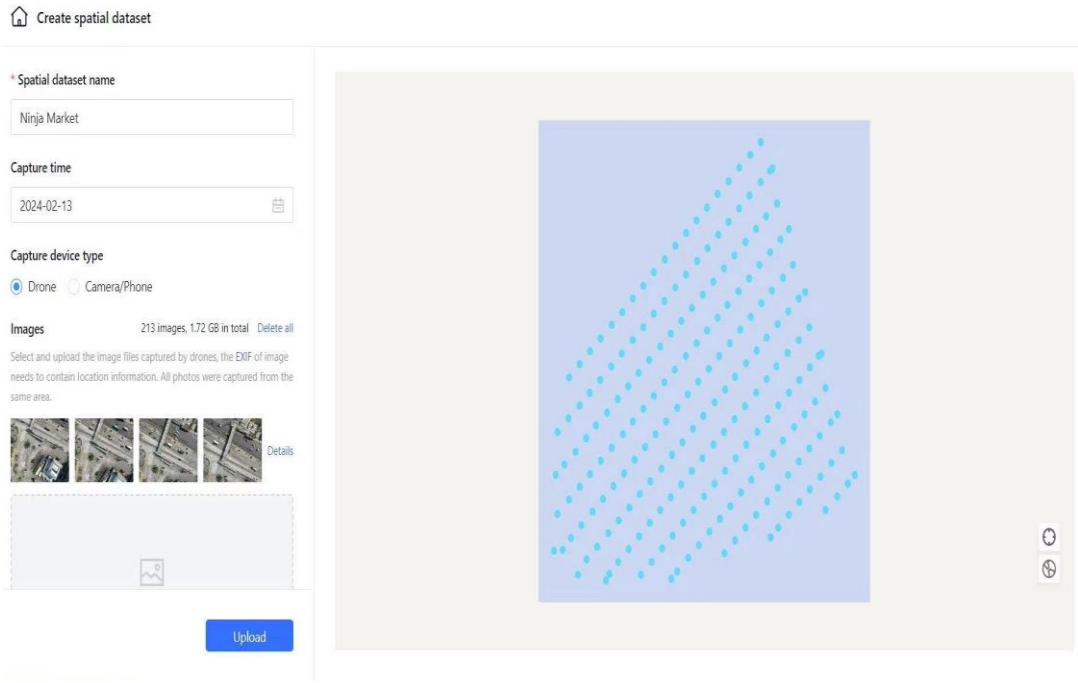


Figure 14: The computed image positions by Get3D Cloud: R2.

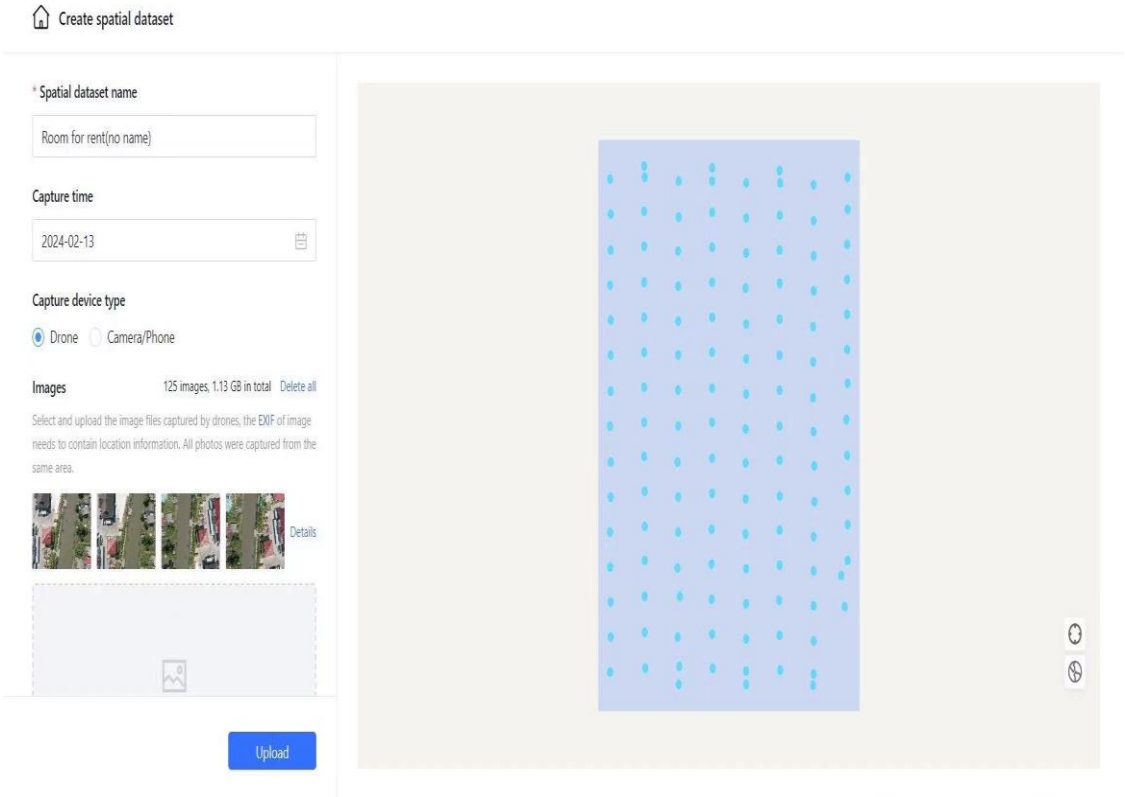


Figure 15: The computed image positions by Get3D Cloud: R3.

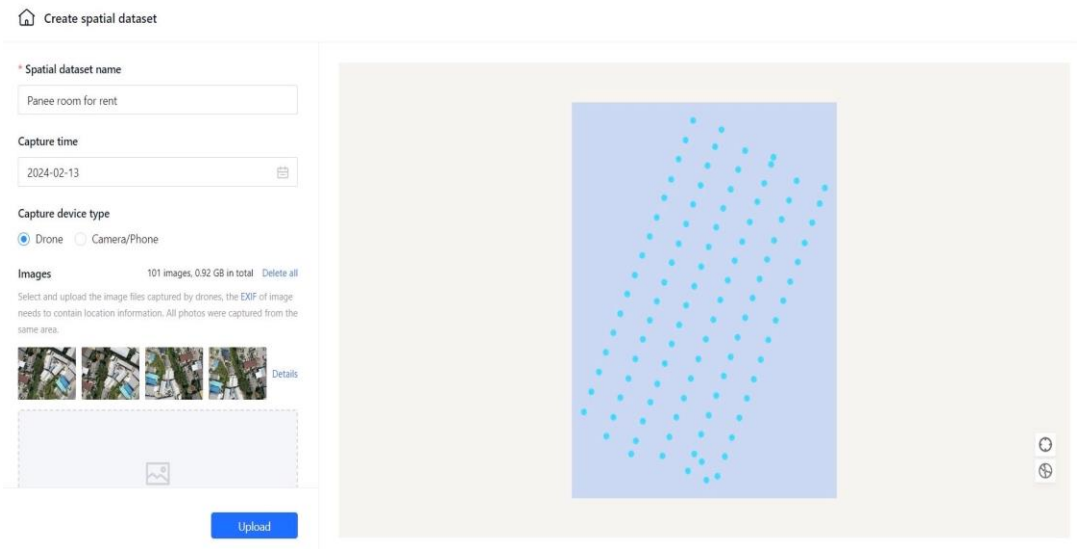


Figure 16: The computed image positions by Get3D Cloud: R4.

3.3 Materials

This study selected crime analysis materials based on police prompt response time to prevent crime, as indicated in Tables 5 and 6.

3.3.1 Instruments

Table 5: List of materials used for risk areas of crime analysis.

Materials	Objectives
Computer Laptop DJI AIR 2s	Data processing Flying to capture images of risk areas
Ipad and smartphone	Display screen while flying drone

3.3.2 Software

Table 6: List of Software used for risk areas of crime analysis.

Software	Objectives
ArcGIS Pro G3D 6.1 software. Or cloud earth of DASPATIAL DJI Fly	Data processing Photo-generated 3D model Drone mapping
Map Pilot Pro	Drone mapping

3.4 Conceptual Framework

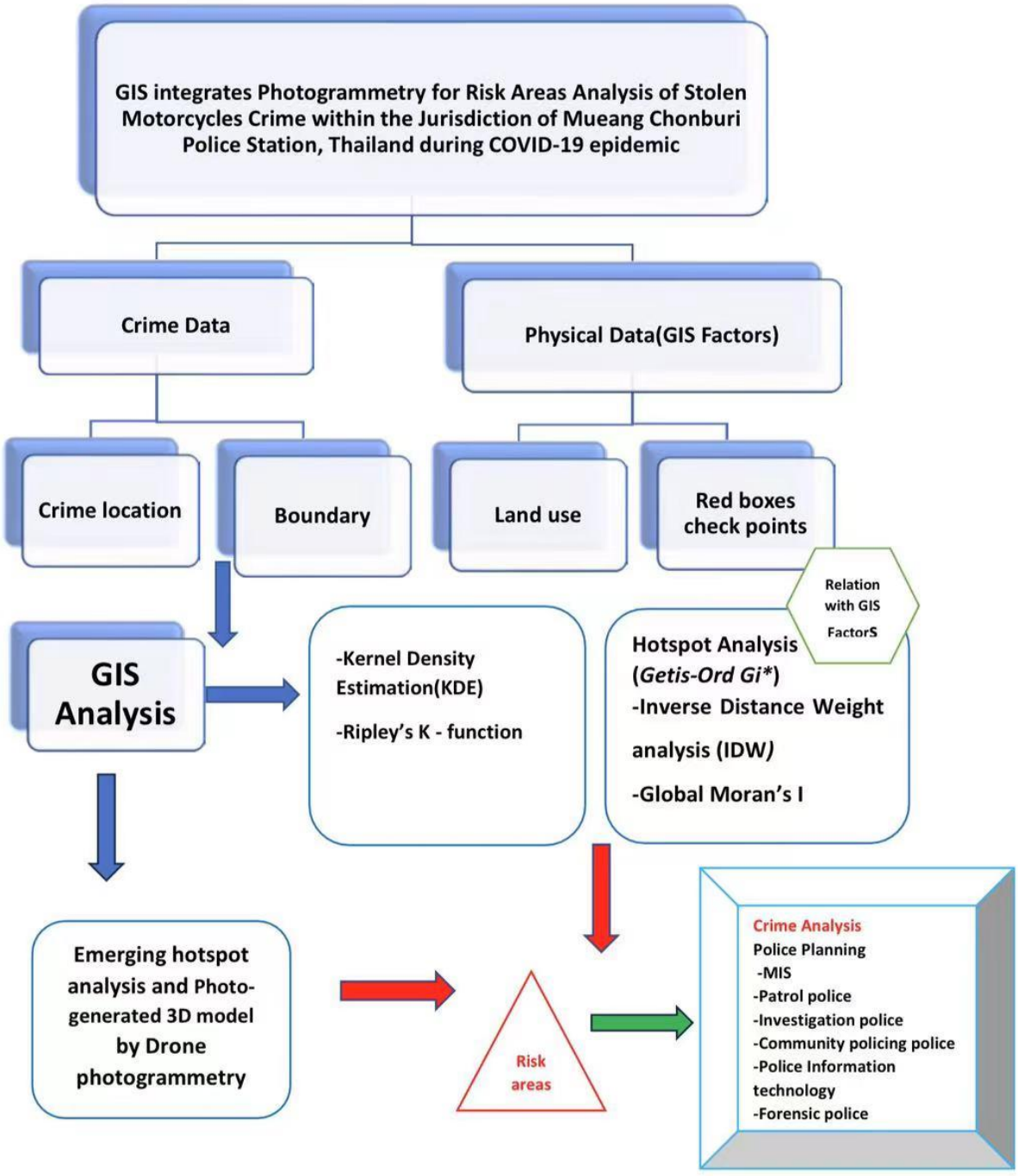


Figure 17: Conceptual Framework.

The integration of spatial analysis and 3D models provides novel insights into the identification and comprehension of areas with high rates of stolen motorcycle crimes. This information will greatly assist the decision-making process of the higher command at the Royal Thai Police Head Office in Bangkok, eliminating the need for on-site visits. They can make a choice within their office and review the report from the police station or other departments. The Emerging Hot Spot Analysis is particularly valuable for police stations to examine the weekly occurrence of crimes. Hot spots are generally understood to be areas of higher than average crime concentration that can be analyzed owing to the inherent geographical qualities within crime hot spot analysis is routinely performed by agencies responsible for community safety, as a means of better defining and understanding crime problems. Hot spot maps are a central part of crime analysis and are frequently used in various stages of the problem-solving process. In addition to their visual role, hot spot maps are habitually generated to stimulate debate between practitioners, with the overarching aim of informing decision-makers about the best course of action to take [46].

CHAPTER NO 4: RESULTS AND VALIDATION

This chapter consists of the results and their discussion, including the scientific reasons for their specific processing.

4.1 Risk Areas Analysis

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

The Getis-Ord Gi* statistics identify spatial clusters of high values (hot spots) and of low values (cold spots). The output of the hot spot analysis tool is GiZScore and GiPValue for each feature. These values represent the statistical significance of the spatial clustering of values, given the conceptualization of spatial relationships and the scale of analysis. A high GiZScore and small GiPValue (probability) for a feature indicates a spatial clustering of high values whereas a low negative GiZScore and small GiPValue indicate a spatial clustering of low values. The higher of GiZScore, the more intense the clustering. A Z score near zero indicates no apparent spatial clustering.

From this, 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 [38]. The collected incident locations were transformed into spatial data, creating a statistically significant local aggregation of activity spaces. The Getis-Ord Gi* method, a spatial statistical approach integrated into ArcGIS Pro was employed to identify hot spots of incident sites. Gi* statistics calculate the ratio of the local sum of values in the vicinity of an incident to the total sum of all values. 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. 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 statistic at varying distances, assessing clustering intensification for each distance. Within this study, risk areas were categorized into four groups based on their corresponding stolen motorcycle densities: low, medium, high, and very high risk areas.

In the year 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 18. 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 19. The aforementioned hot spots function as markers of areas with heightened risk, often impacted by several factors including police red box checkpoints, land use, and the number of patrol police [36].

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 18

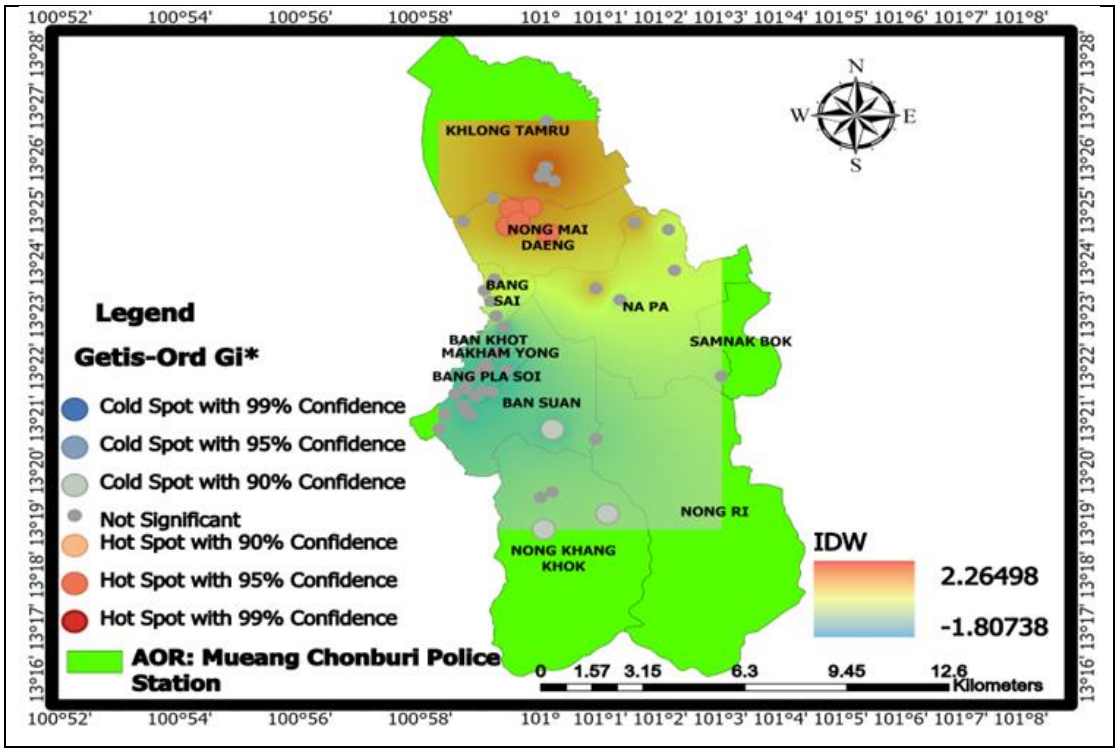


Figure 18: Getis-Ord Gi*/IDW hot spot analysis results, 2019.

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 19.

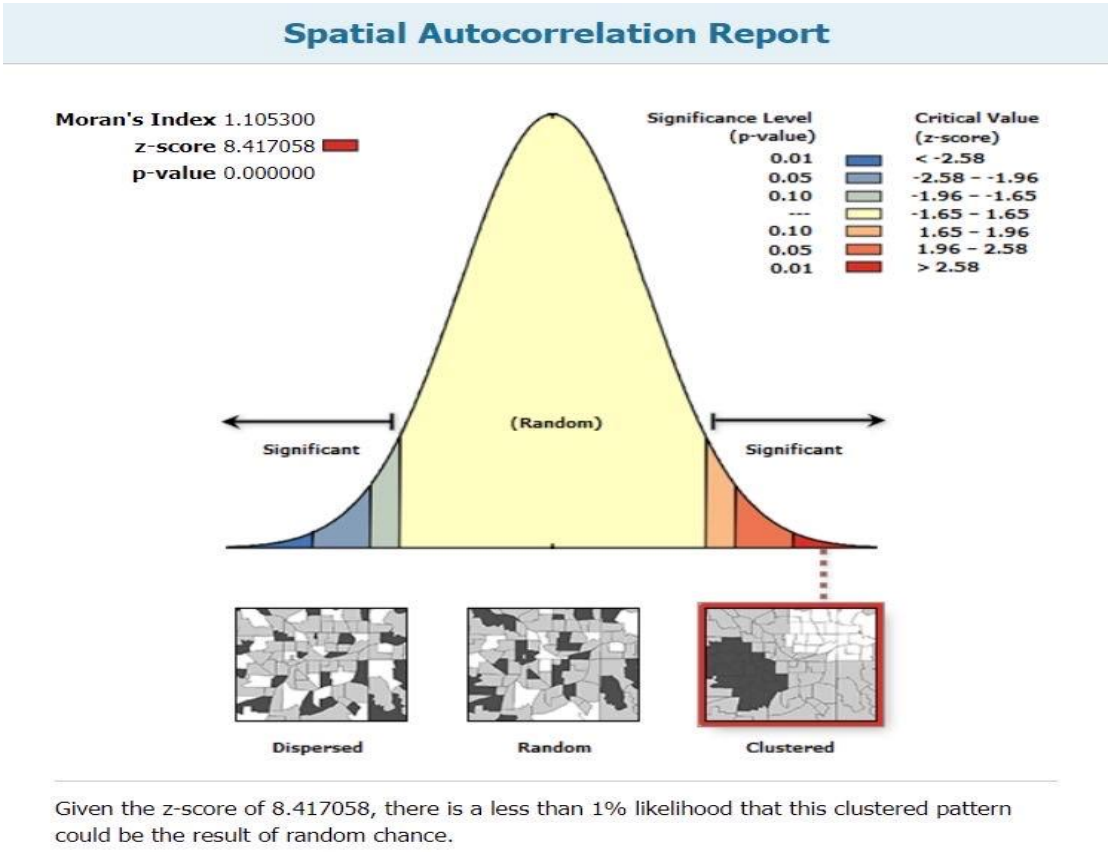


Figure 19: Global Moran's I index 2019.

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 z-score was 8.417058 and the p-value was 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[47].

The Getis Ord Gi* and IDW did not produce any results in 2020. Thailand has experienced the impact of the COVID-19 epidemic in the current year. There was a total of 22 occurrences of motorbike theft in the study area, which influenced the results of the crime analysis. One method that can identify risk areas simply based on its outputs is the Kernel Density Estimation (KDE) algorithm.

In the year 2021, 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 the Nong Mai Daeng district area is significantly impacted by stolen motorcycle incidents with medium-risk confidence at 90% as shown in Figure 20. 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 21 [36]. 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 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 while Bang Pla Soi, 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 20.

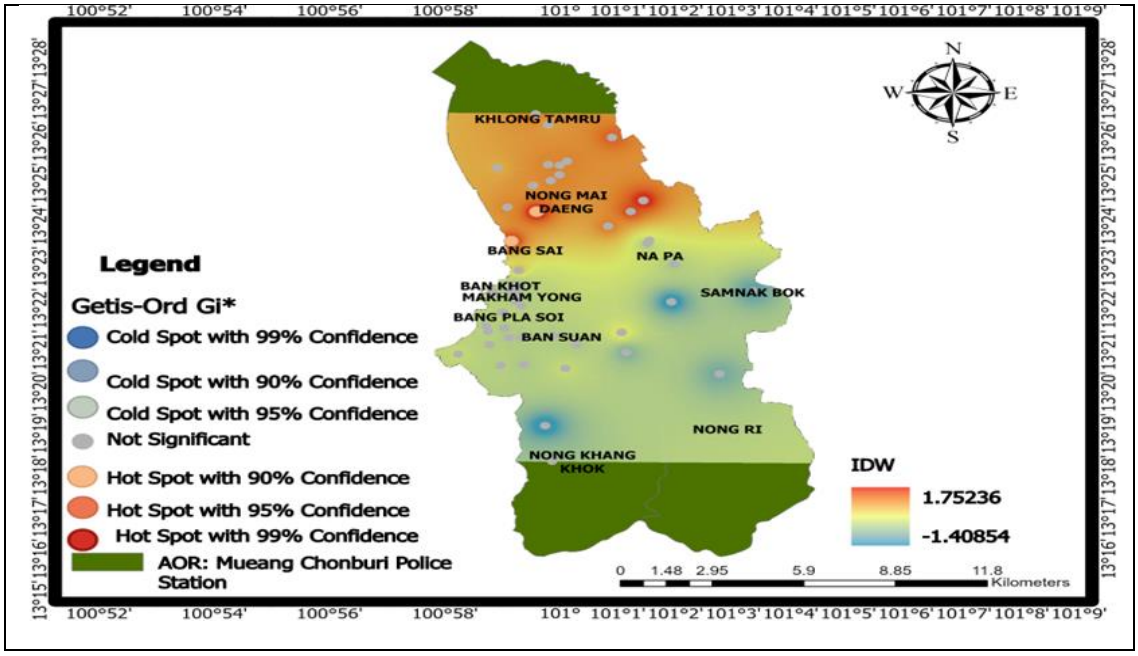


Figure 20: Getis-Ord Gi*/IDW hot spot analysis results, 2021.

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 21.

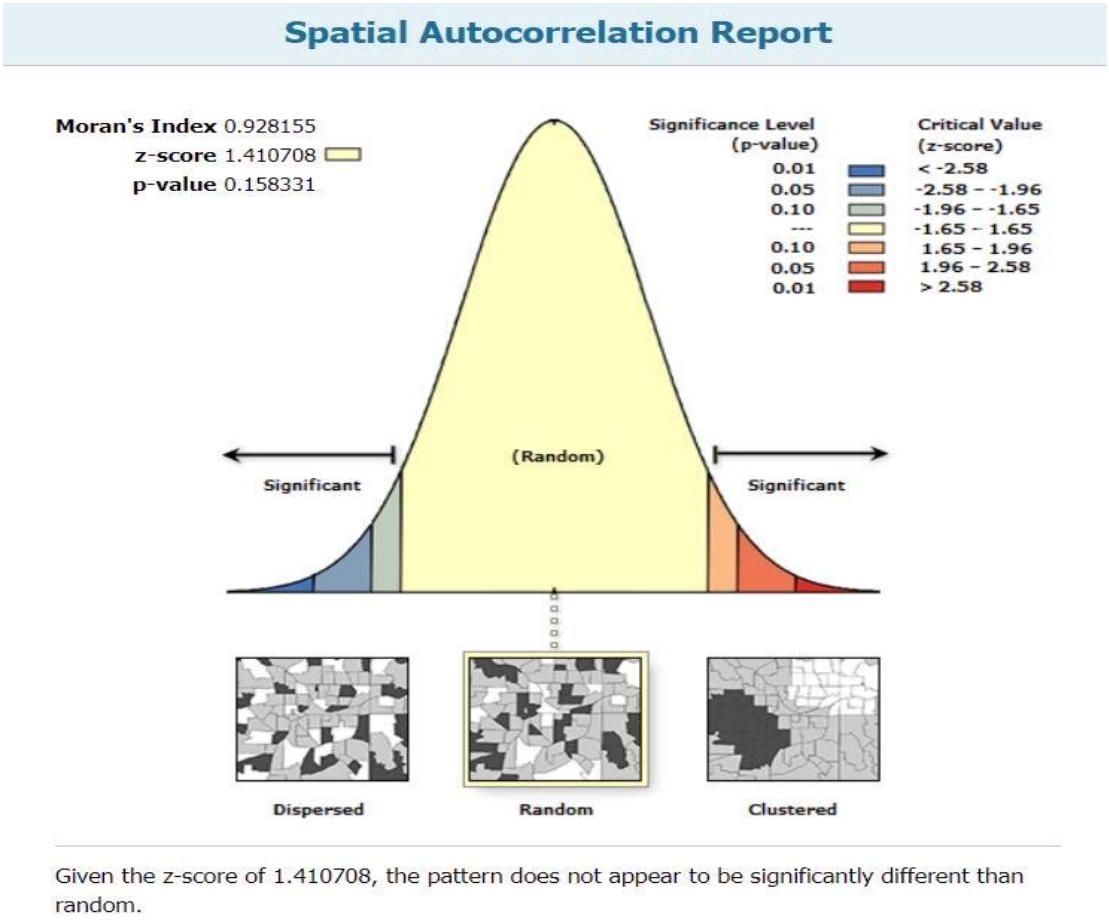


Figure 21: Global Moran's I index 2021.

In the year 2021, the value of Moran's I index was positive as 0.928155, which shows randomly stolen motorcycles in the study area. The z-score for crashes was 1.410708 and the p-value was 0.158331. The assumption of random distribution for stolen motorcycles was accepted because the z-score was 1.410708. Given the z-score of 1.410708, the pattern does not appear to be significantly different from than random[47].

In the year 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 22. 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[36]. 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 22.

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 23.

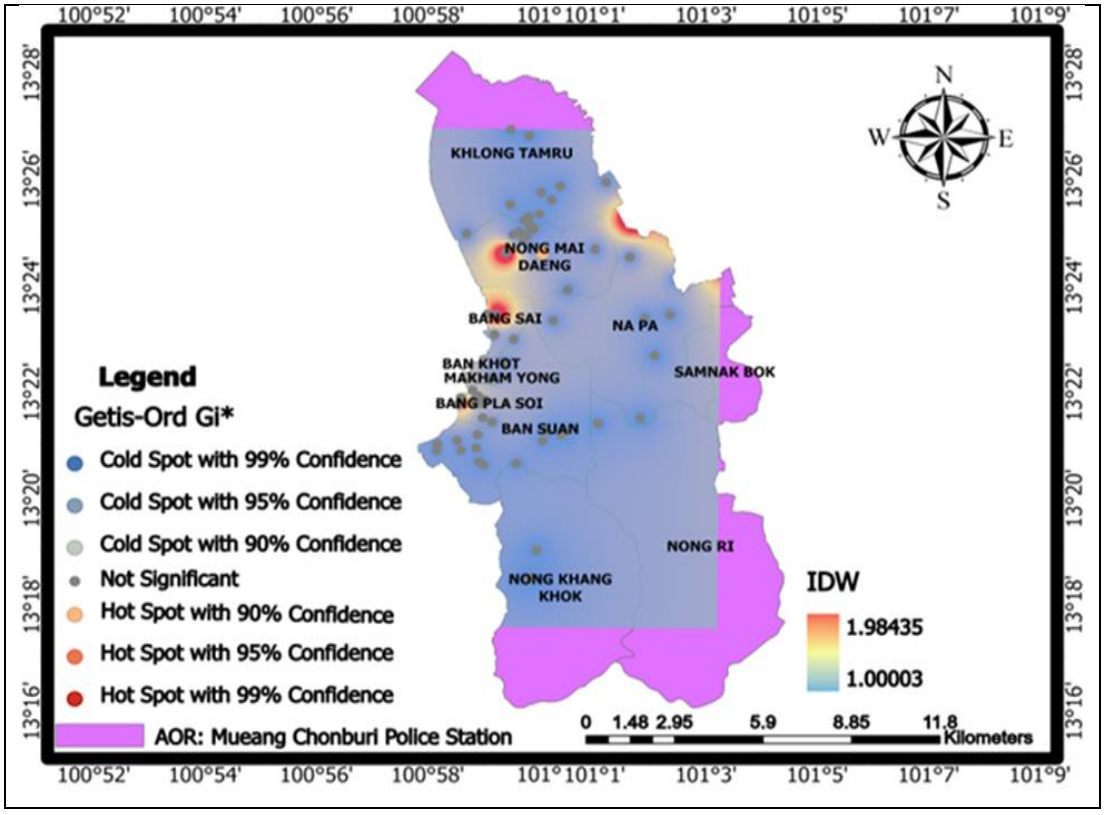


Figure 22: Getis-Ord Gi*/IDW hot spot analysis results, 2022.

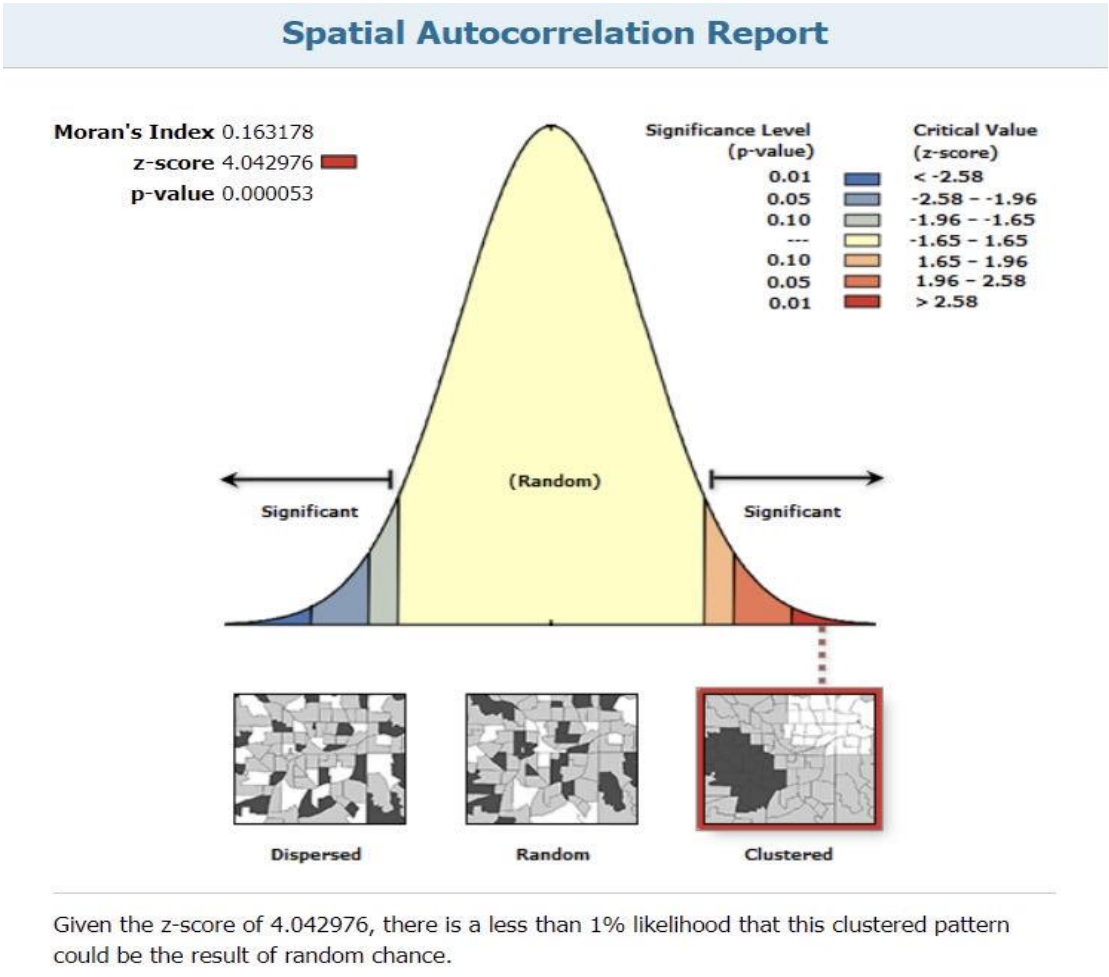


Figure 23: Global Moran's I index 2022.

In the year 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[47].

In the year 2023, Through the hot spot analysis of the Mueang Chonburi Police Station area of responsibilities using Gi* statistics, it becomes evident that the Nong Mai Daeng district

area is significantly impacted by stolen motorcycle incidents as very high-risk confidence at 99 % as shown in Figure 24. Areas with very high positive Gi* scores on the map indicate the presence of concentrated motorcycle theft crime. Gi* > 2.58 at Nong Mai Daeng areas[36]. 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, 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 are very low-risk crime area as shown in Figure 24.

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 25.

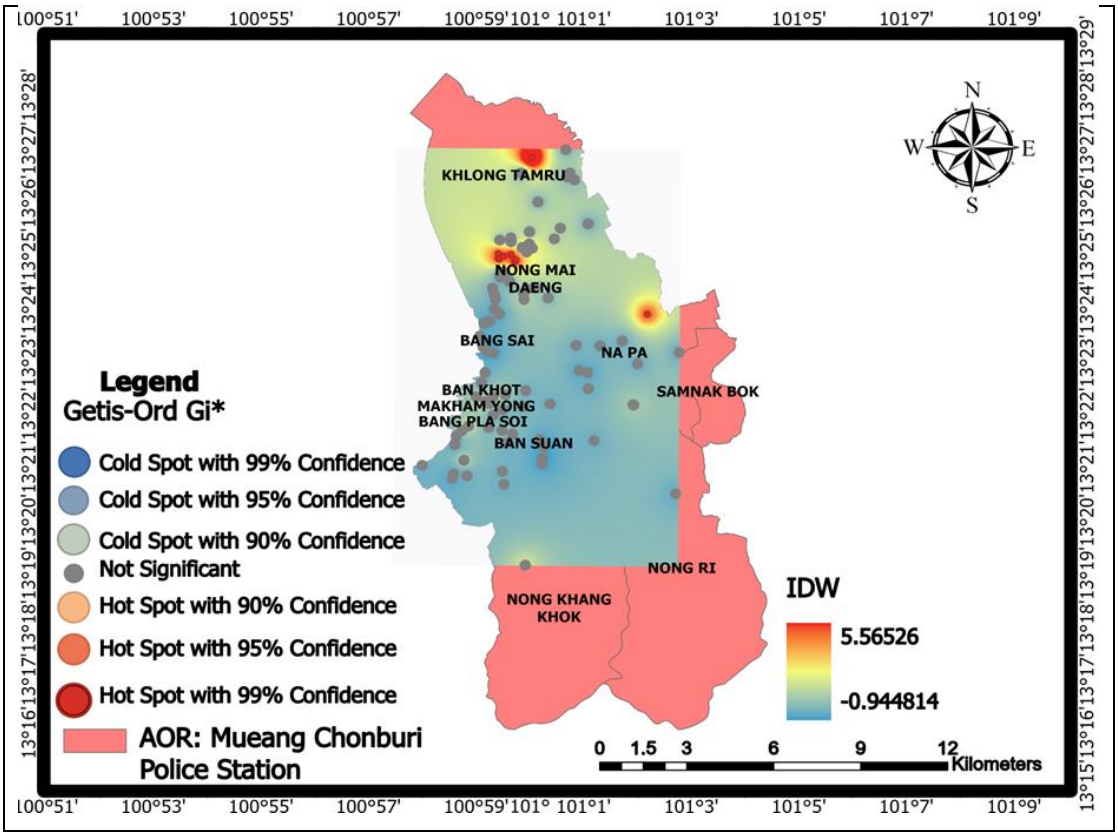


Figure 24: Getis-Ord Gi*/IDW hot spot analysis results, 2023.

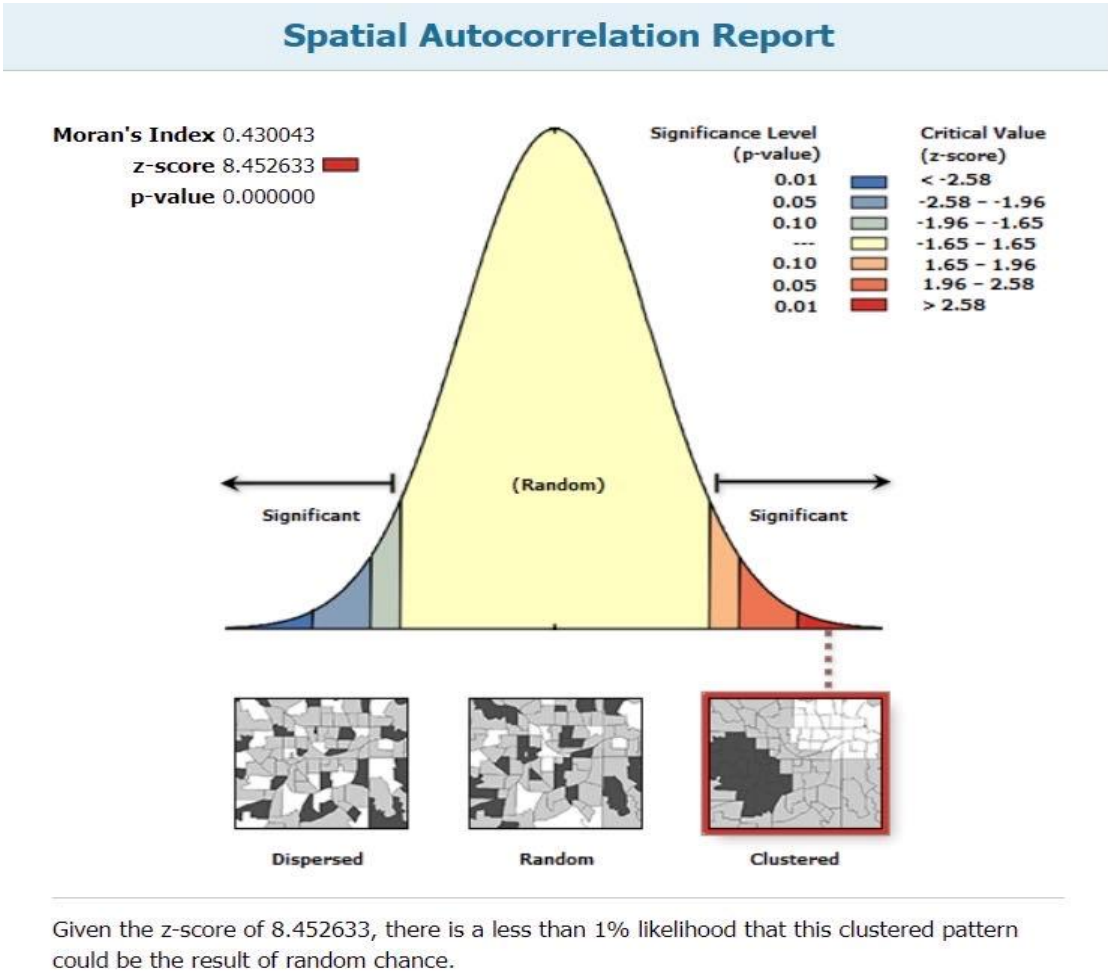


Figure 25: Global Moran's I index 2023.

In the year 2023, the value of Moran's I index was positive as 0.430043 which shows a significant clustering of stolen motorcycles in the study area. The z-score was 8.452633 and the p-value was 0.00. The assumption of random distribution for stolen motorcycles was rejected because given the z-score of 8.452633, there is a 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[47].

4.1.2 The Comparison of Hot Spot Analysis between Getis-Ord Gi*/IDW and Kernel Density Estimation (KDE)

Hot spots are typically recognized as regions with a higher concentration of criminal activity, which can be studied due to the intrinsic geographic characteristics associated with crime.

Agencies responsible for community safety routinely conduct hot spot analysis to more accurately define and comprehend crime issues. Hot spot maps play a crucial role in criminal investigation and are commonly utilized at different phases of the problem-solving process. Hot spot maps serve not just a visual purpose, but also commonly inspire discussion among professionals, with the overarching aim of informing decision-makers about the best course of action to take.

Recently, there has been an emergence of assessment literature that provides evidence for the effectiveness of 'hotspot policing' in reducing high crime counts or rates in small, specified places. For instance, in Jersey City, New Jersey, law enforcement focused their efforts on identified areas with high drug activity. This led to a decrease in the number of emergency calls for disorder-related incidents in the high-crime regions and also seemed to have a positive impact on the neighboring communities. In the UK, "high visibility patrolling" or "saturation patrols" are frequently used as the standard tactical response to crime issues.

Practitioners are drawn to KDE due to several elements that contribute to its popularity. Firstly, it successfully addresses the Modifiable Areal Unit Problem. KDE is independent of administrative boundaries and hence better aligns with the actual distribution of crime. Furthermore, it is a straightforward task to generate. The leading GIS software providers have developed extensions that enable users to easily generate KDE maps with only a few mouse clicks. Furthermore, it is straightforward to interpret. Hot spots are visually depicted with heated colors like red, while locations with lower crime rates are represented with cooler hues such as light yellow or blue. Furthermore, it possesses an aesthetically pleasant appearance. When comparing KDE maps to point or grid thematic mapping, KDE maps are visually appealing. Furthermore, it exhibits statistical robustness. The algorithm applied to data in a KDE is consistent, regardless of the distribution or form of the data. In addition, additional statistical tests can be applied to a KDE map output, such as the Gi and Gi* statistics, which integrate statistical significance into hotspot detection [46].

The KDE function has provided a smooth surface of the intensity of crime while the Gi* statistics have provided a statistically significant hot spot based on the

high value of surrounding areas. The weighted interpolation method Inverse Distance was used to better visualize the outcome of the Getis-Ord Gi* hot spot analysis. Together may provide the best crime hotspot in the study area and thus may be considered as complementary rather than replacements for each other[26]. Almost similar locations were identified as crime hot spots from all three methods. The KDE method has shown several hot spots as compared to the other 2 methods.

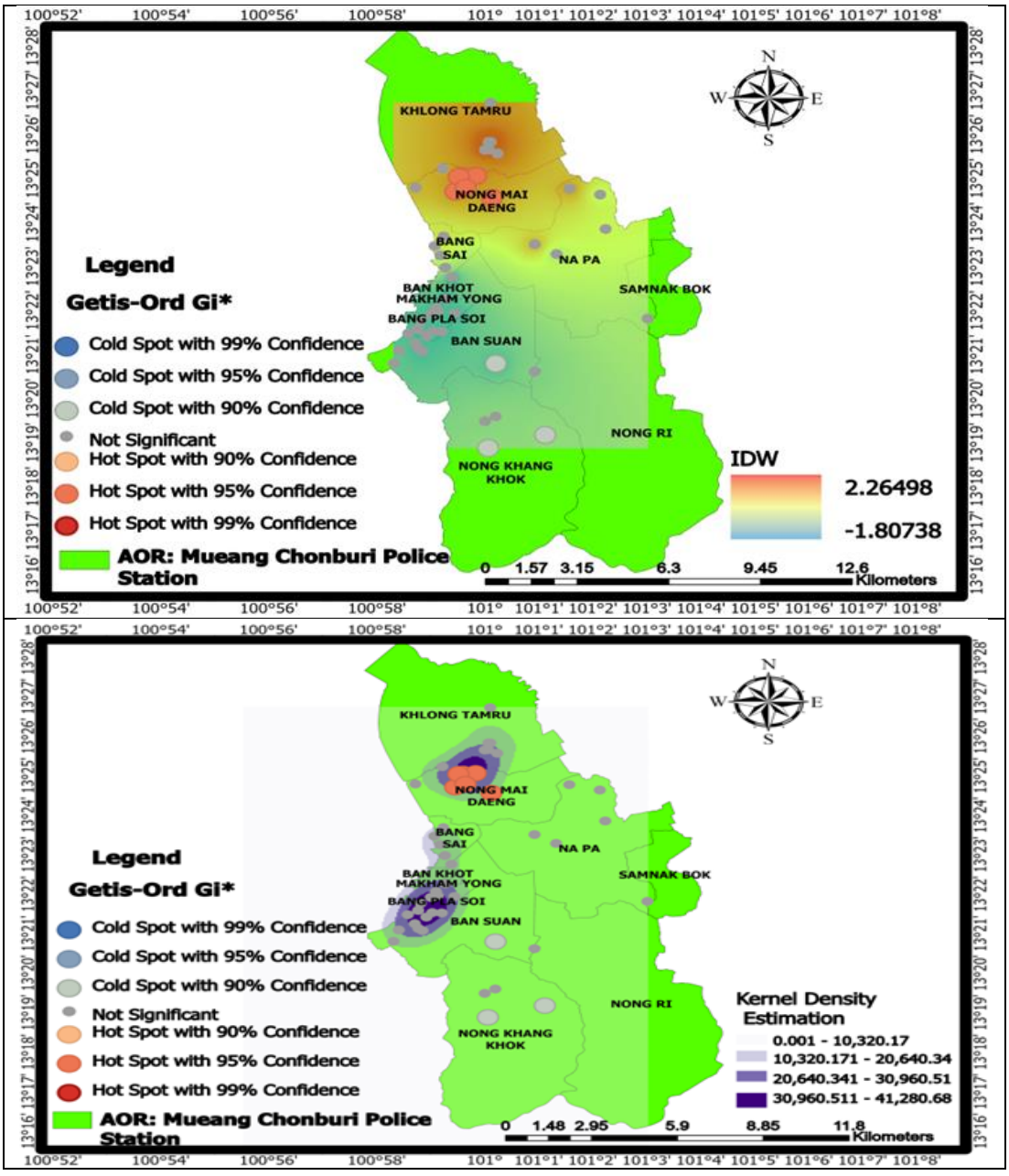


Figure 26: The comparison of results between Getis-Ord Gi*/IDW (top); Kernel Density Estimation(KDE) (bottom), 2019.

In the year 2019, the KDE map of the overall crime is presented in Figure 26. The risk areas in these figures indicate the level of crime in Nong Mai Daeng, Khlong Tamru, and Bang Pla Soi, classifying them as very high-risk locations. The scale is displayed on the right side of the diagrams. Unshaded areas had no significant stolen motorcycle crimes within the specified time frame. The comparison of findings between Getis-Ord Gi*/IDW (top) and Kernel Density Estimation(KDE) (bottom), 2019 is depicted in Figure 26. The findings from the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) models indicate that crime hot spots are centered in Nong Mai Daeng, with locations exhibiting high, very high, and very high risk of stolen motorbikes, respectively as presented in Figure 26. The results of the Emerging Hot Spot analysis are not available as the number of motorcycle theft incidents this year is below 60.

In the year 2020, the Kernel Density Estimation (KDE) algorithm was the sole method capable of predicting risk zones. Thailand has been affected by the COVID-19 pandemic this year. The study area had a total of 22 instances of motorbike theft, which had an impact on the outcome of the crime analysis. The KDE map depicted in Figure 27 illustrates the overall crime data. The shading of the areas in this figure corresponds to the level of crime in Nong Mai Daeng and Khlong Tamru, which are classified as highly high-risk locations. The diagrams display the scale on the left side. Areas devoid of shading did not experience any notable criminal activities within that time frame.

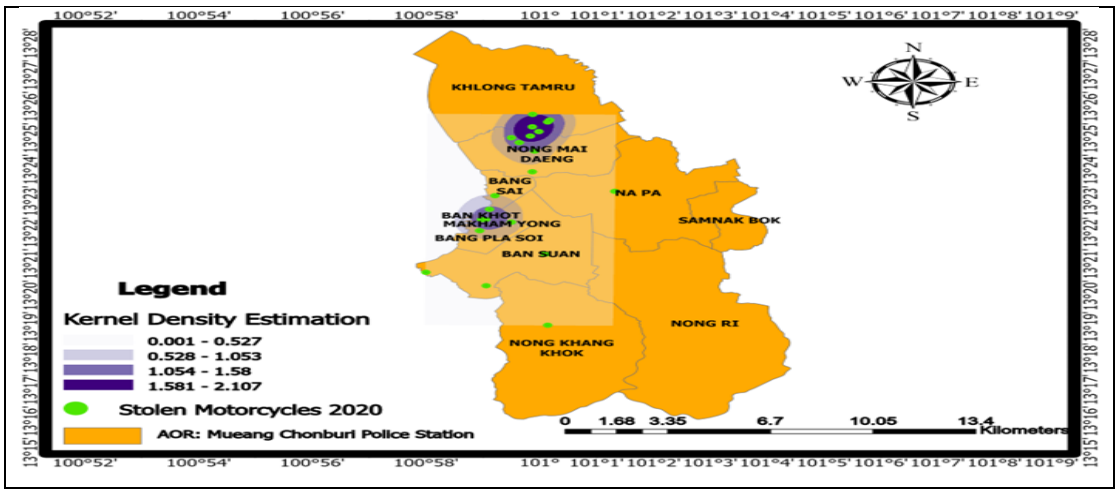


Figure 27: Kernel Density Estimation (KDE) 's result 2020.

The KDE map for overall crime in 2021 is depicted in Figure 28. The shading of the areas in this figure indicates the level of criminal intensity, as very high risk in Ban Khot and Makham Yong. Nong Mai Daeng exhibits high-risk levels in some areas.

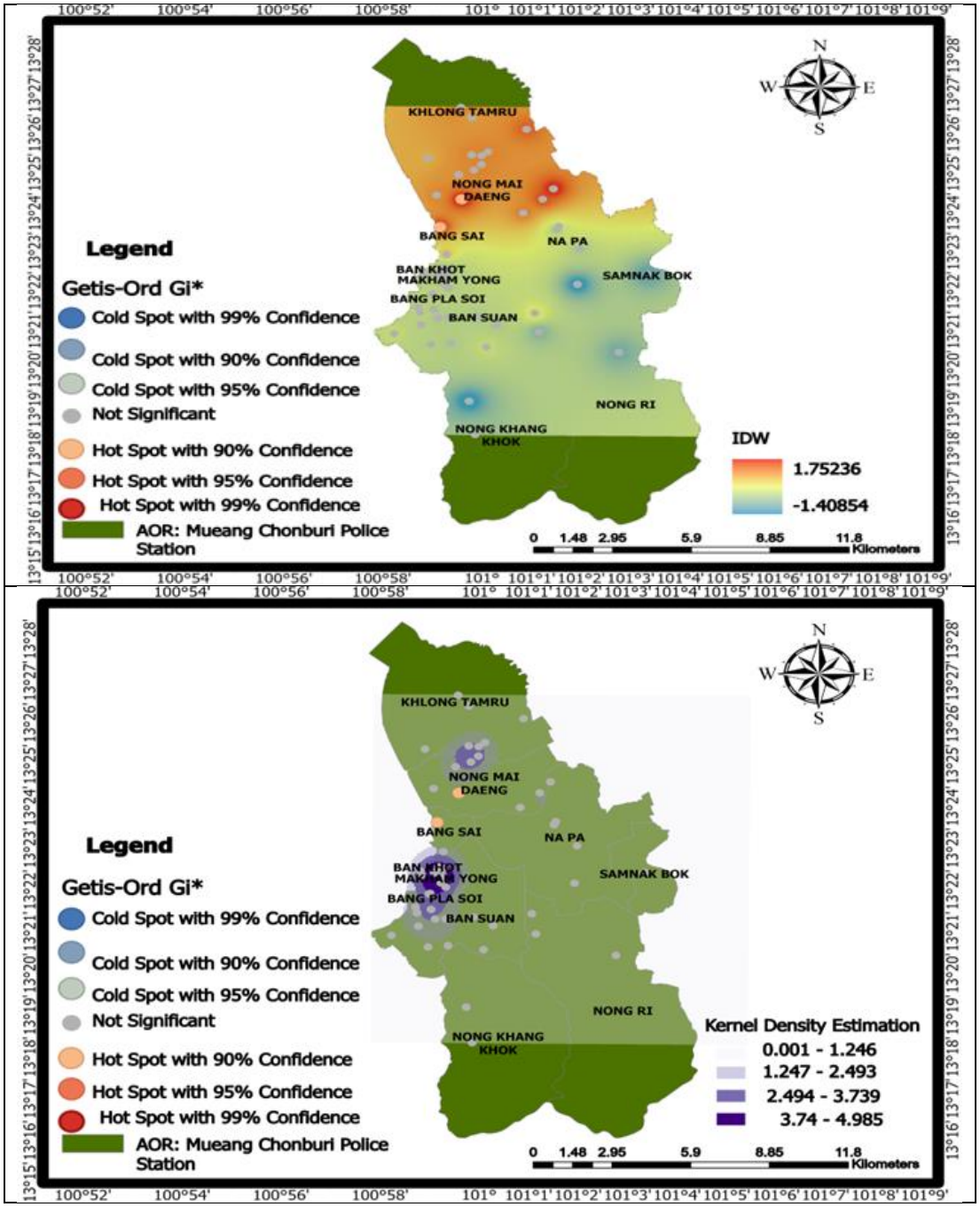


Figure 28: The comparison of results between Getis-Ord Gi*/IDW (top); Kernel Density Estimation(KDE) (bottom), 2021.

The diagrams display the scale on the right side. Unshaded areas had no significant stolen motorcycle crimes within the specified time frame. The comparison of findings between Getis-Ord Gi*/IDW (top) and Kernel Density Estimation(KDE) (bottom), 2021 is depicted in Figure 28. The findings of the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) methodologies indicate that crime hot spots are centered in Nong Mai Daeng, classified as medium-risk areas, very high-risk areas, and high-risk areas, respectively. Both the Getis-Ord Gi* and IDW models yield comparable predictions for the concentration of crime hot spots indicating that Bang Sai is classified as medium and very high-risk for stolen motorcycles, respectively. The examination of Emerging Hotspot Analysis revealed the identification of new hot spot patterns in Khlong Tamru, as depicted in Figure 42.

The KDE map depicting the overall crime in 2022 is presented in Figure 29. The shading of the areas in this figure indicates the level of criminal intensity, as very high - risk inside Nong Mai Daeng, Khlong Tamru, and Bang Pla Soi. The scale is shown on the right of the diagrams. Unshaded areas had no significant stolen motorcycle crimes within the specified time frame. The comparison of findings between Getis-Ord Gi*/IDW (top) and Kernel Density Estimation (KDE) (bottom), 2022, is depicted in Figure 29.

There was an increase in the number of stolen motorbike instances compared to the previous year, with a total of 78 recorded incidents. The police should take notice of the escalating crime rate and take proactive measures to address the issue or prevent crime from spreading. There were 146 occurrences of stolen motorcycles in the year following 2022, indicating a lack of crime prevention measures in these locations. This demonstrates the significance of crime analysis in the context of crime prevention. If the police fail to prevent crime, it will lead to the proliferation of criminal activities.

Based on the analysis of stolen motorcycle crime data spanning four years, it becomes evident that certain areas exhibit a recurring pattern of crime hot spots. The study of high-risk locations is crucial for addressing the challenges.

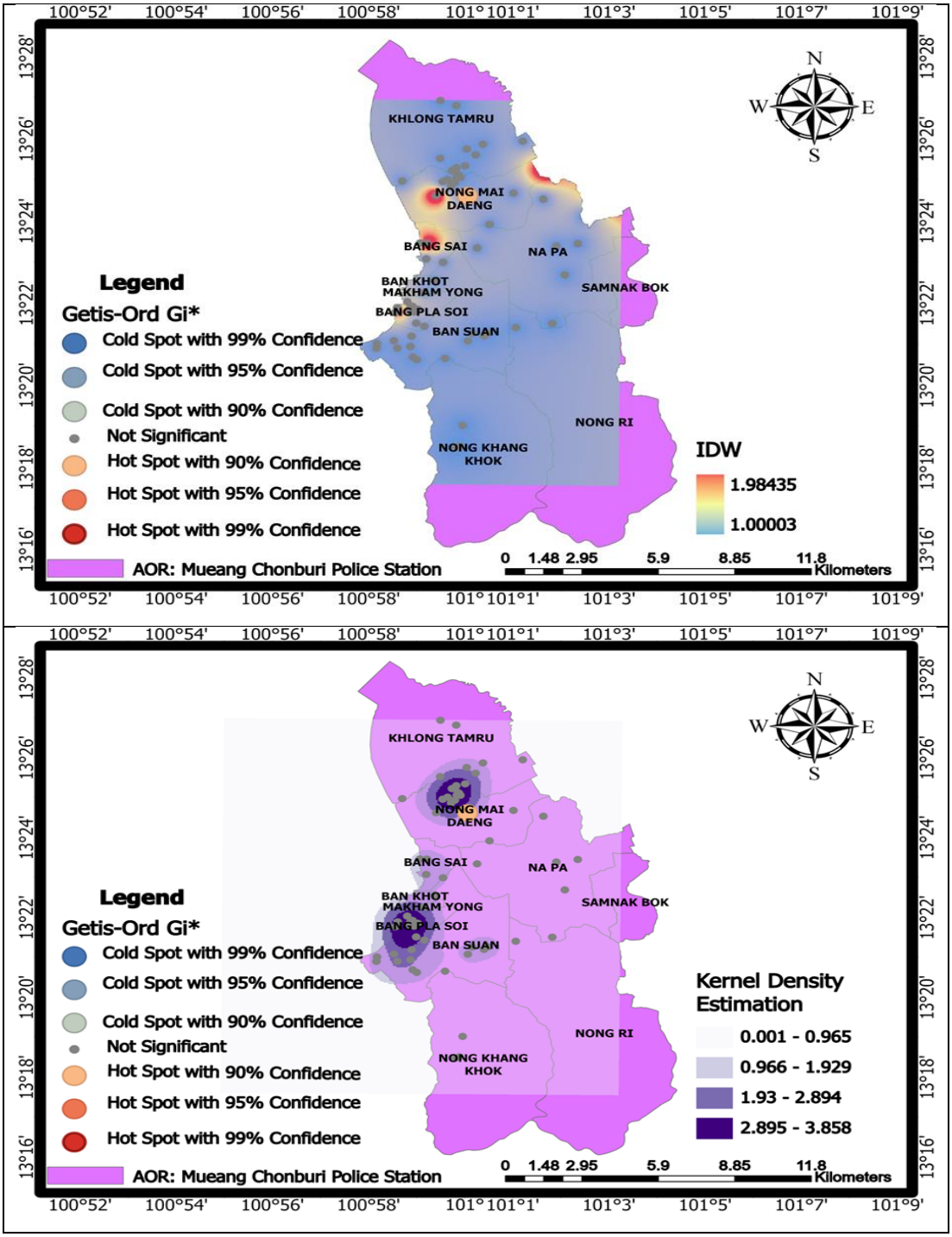


Figure 29: The comparison of results between Getis-Ord Gi*/IDW (top); Kernel Density Estimation(KDE) (bottom), 2022.

The findings using the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) methodologies indicate that crime hot spots are centered in Nong Mai Daeng, classified as medium-risk areas, very high-risk areas, and very high-risk areas,

respectively. Both the IDW and Kernel Density Estimation models yield comparable predictions for the concentration of crime hot spot indicating that Bang Pla Soi is classified as very high-risk for stolen motorcycles, respectively. The examination of Emerging Hot Spots Analysis revealed the identification of new hot spot patterns in Nong Mai Daeng, as depicted in Figure 43.

By the year 2023, The results of the Kernel Density Estimation (KDE) technique, were generated for the entire crime, as displayed in Figure 30. The shading of the areas in this figure indicates the level of criminal intensity, as very high - risk within Nong Mai Daeng. The scale is shown on the right of the diagrams. Unshaded areas had no significant stolen motorcycle crimes within the specified time frame. The comparison of findings between Getis-Ord Gi*/IDW (top) and Kernel Density Estimation (KDE) (bottom), 2023, is depicted in Figure 30. The findings from the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) methodologies indicate that crime hot spots are located in Nong Mai Daeng, which are recognized as very high-risk locations for motorcycle theft.

The findings from the Getis-Ord Gi* and IDW models align with their predictions that crime hot spots are located in Khlong Tamru and Na Pa, which are identified as very high-risk locations for motorcycle theft. The identification of sporadic hot spot risk locations in Nong Mai Daeng was conducted by Emerging Hot Spot Analysis, as depicted in Figure 44. The year 2023 witnessed the highest incidence of stolen crime, with a total of 146 incidents. Notably, all three approaches employed yielded similar outcomes, with a particular focus on Nong Mai Daeng. This is due to the resumption of industrial employment by workers resumed industrial employment after the lockdown of COVID-19. Therefore, there was a significant increase of people in rental demand for living in this area.

Consequently, it is imperative to promptly address this crime to mitigate its potential ramifications on both human lives and property.

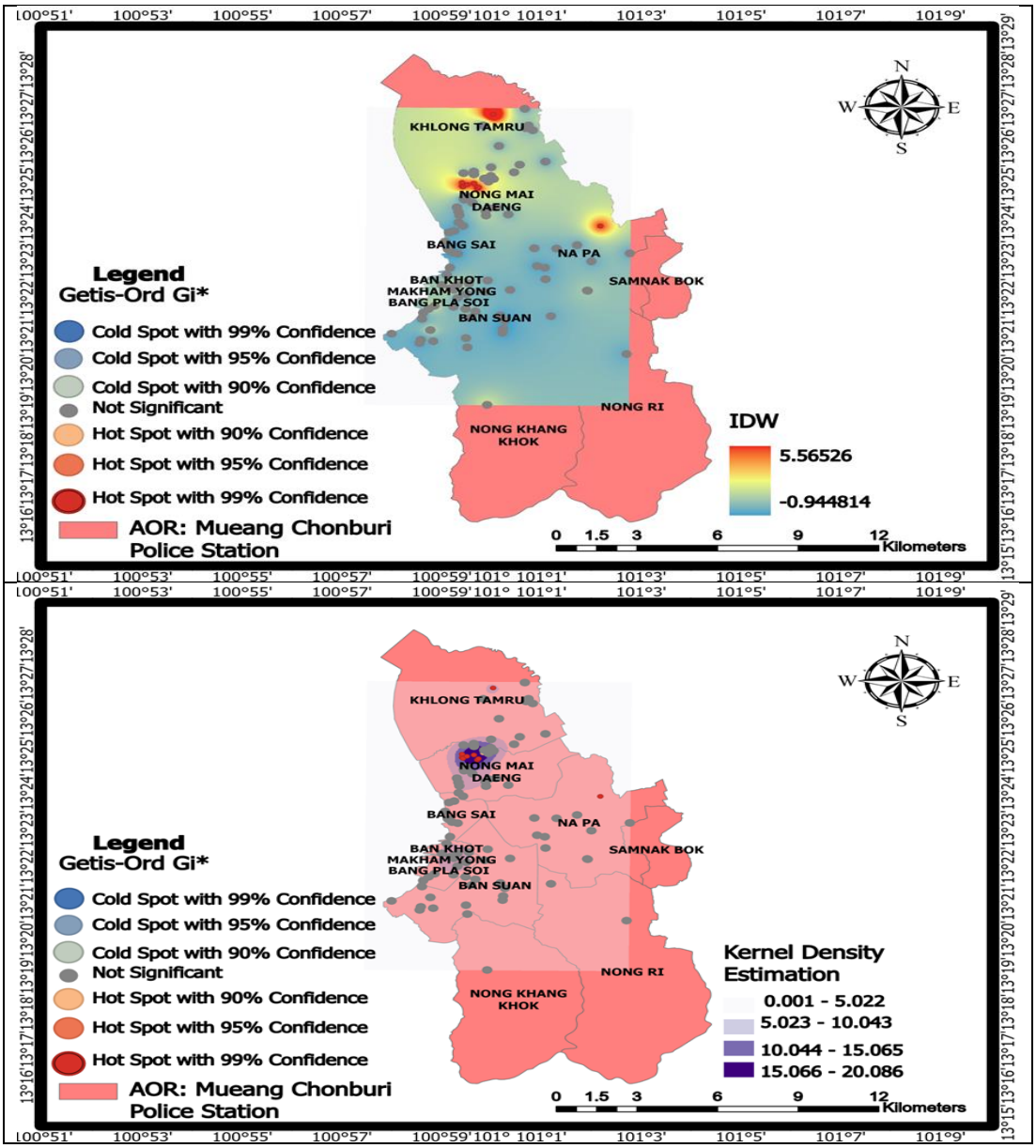
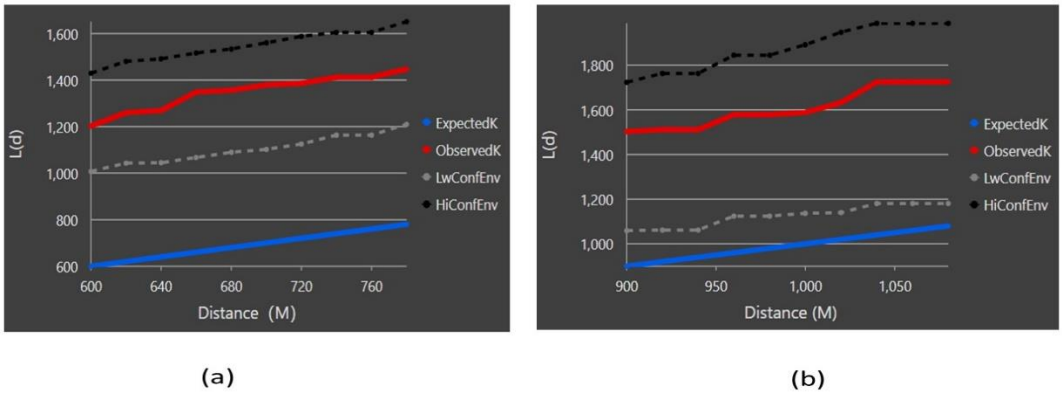


Figure 30: The comparison of results between Getis-Ord Gi*/IDW (top); Kernel Density Estimation(KDE) (bottom), 2023.

4.1.3 The Results of Ripley's K Function

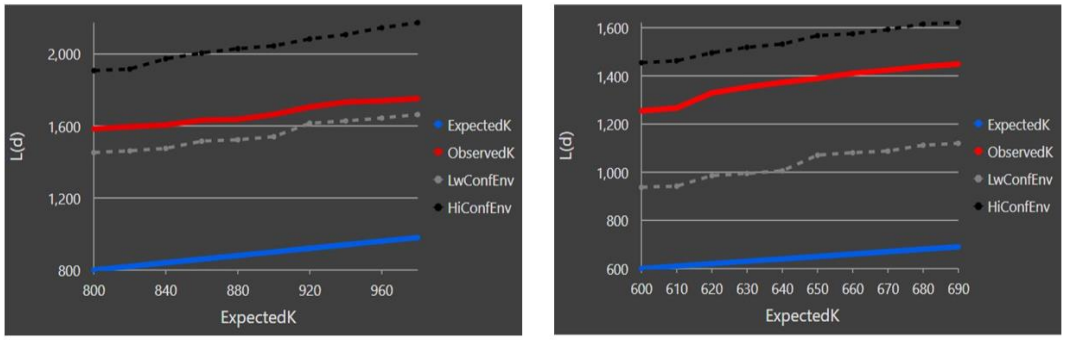
Using the analysis tool of Ripley's K, the spatial distribution pattern of stolen motorcycles within the jurisdiction of Mueang Chonburi Police Station. The same distribution characteristic of motorbike theft is found to be spatially clustered in these 5 years as shown in Fig. 31(a), 31(b), 32(c), 32(d), and 33(e). For the values of

ObservedK which are smaller than those of HiconfEnv, the statistical tests of 5 years show that the cluster distributions but not significant.



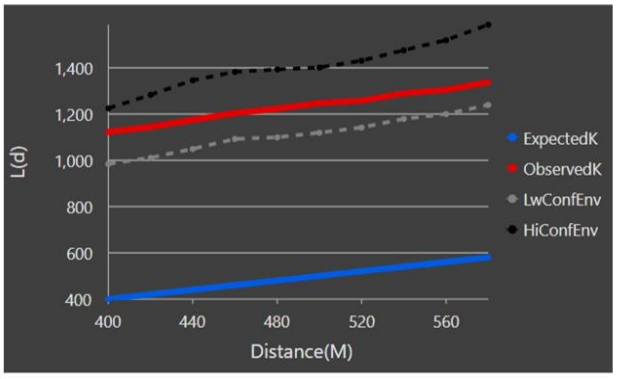
(a) (b)

Figure 31: The result of Ripley's K function (a) 2019; (b) 2020.



(c) (d)

Figure 32: The result of Ripley's K function (c) 2021; (d) 2022.



(e)

Figure 33: The result of Ripley's K function (e) 2023.

4.1.4 The Correlation between Risk Areas and Police Red Box Checkpoints

This section of the study will concentrate on similar results of risk areas using three different methods: Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE). Additionally, the research will overlay risk areas with 408 police red box checkpoints. The findings from the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) in 2019 indicate that crime hotspots were primarily located in Nong Mai Daeng, with areas classified as high, very high, and very high-risk for stolen motorbikes, respectively as shown in Table 7. In 2020, the algorithm Kernel Density Estimation (KDE) was the only method capable of accurately predicting risk areas, revealing that Nong Mai Daeng and Khlong Tamru are classified as very high-risk zones. Thailand has been affected by the COVID-19 pandemic this year. The study area had a total of 22 instances of motorbike theft, which had an impact on the outcome of the crime analysis.

Similar to the findings in 2021, the results obtained from the method incorporating Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) indicate that criminal hot spots of stolen motorbikes were predominantly concentrated in Nong Mai Daeng. These areas were classified as medium-risk, very high-risk, and high-risk, respectively. The findings from the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) in 2022 indicate that crime hotspots were predominantly located in Nong Mai Daeng, with areas classified as medium-risk, very high-risk, and very high-risk in terms of stolen motorcycles, respectively.

In 2023, according to the findings of Getis-Ord Gi*, IDW, and Kernel Density Estimation, it is evident that Nong Mai Daeng remains the location with the very high risk in terms of stolen motorbikes, as compared to other areas. These predictions indicate that crime hot spots are concentrated in Nong Mai Daeng, making it a very high-risk area. Therefore, based on the findings of a five-year data analysis, it can be concluded that Nong Mai Daeng exhibits the highest level of risk. All three methodologies have yielded consistent findings that Nong Mai Daeng consistently poses the risk of motorcycle theft each year, but with varying degrees of risk. The comparative results of the stolen motorcycle risk areas analysis 2019 – 2023 are presented in Table 7. The data shown in Figures 34, 35, 36, 37, and 38 illustrates the

correlation between 408 police red box checkpoints and risk areas in Nong Mai Daeang from 2019 to 2023.

Table 7*:* The results of four methodologies for stolen motorcycle risk areas analysis 2019 – 2023.

Year	Hot Spot Getis Ord Gi*	Inverse Distance Weight (IDW)	Kernel Density Estimation (KDE)	Emerging Hot Spot Analysis
2019	Nong Mai Daeng(high) Confidence at 95% Gi* = 1.96-2.58	Nong Mai Daeng and Khlong Tamru (very high)	Nong Mai Daeng , Khlong Tamru and Bang Pla Soi (very high)	No result
2020	No result	No result	Nong Mai Daeng and Khlong Tamru (very high)	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)	Ban Khot and Makham Yong (very high) Nong Mai Daeng (high)	New Hot Spot at Khlong Tamru
2022	Nong Mai Daeng (medium) Confidence at 90% G* = 1.65 -1.96	Nong Mai Daeng ,Bang Sai and Bang Pla Sroy (very high)	Nong Mai Daeng, Khlong Tamru and Bang Pla Soi (very high)	New Hot Spot at Nong Mai Daeng
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)	Nong Mai Daeng (very high)	Sporadic Hot Spot at Nong Mai Daeng

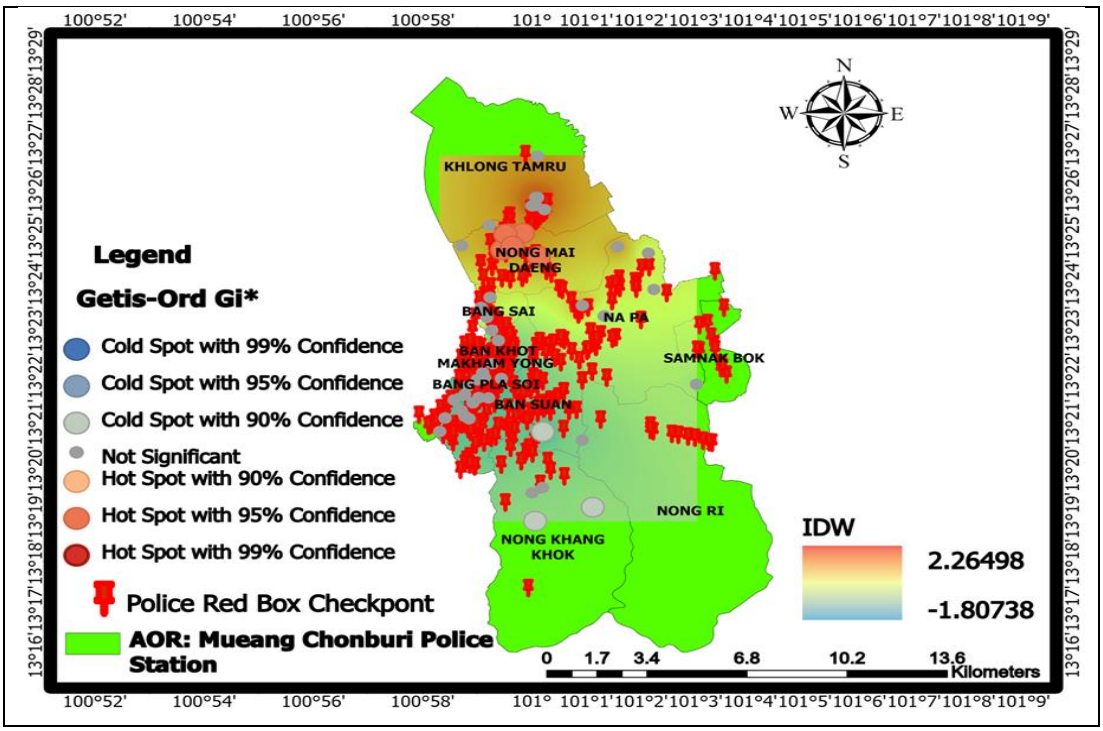


Figure 34: The relationship between risk area Nong Mai Daeng and police red box checkpoints in 2019.

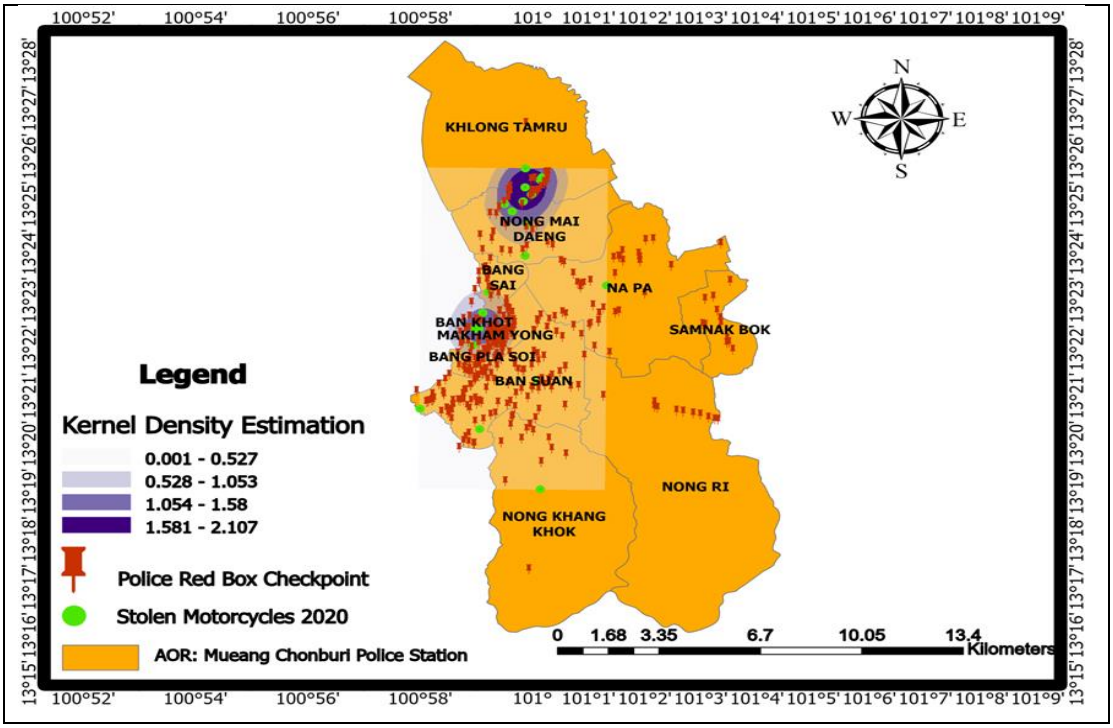


Figure 35: The relationship between risk area Nong Mai Daeng and police red box checkpoints in 2020.

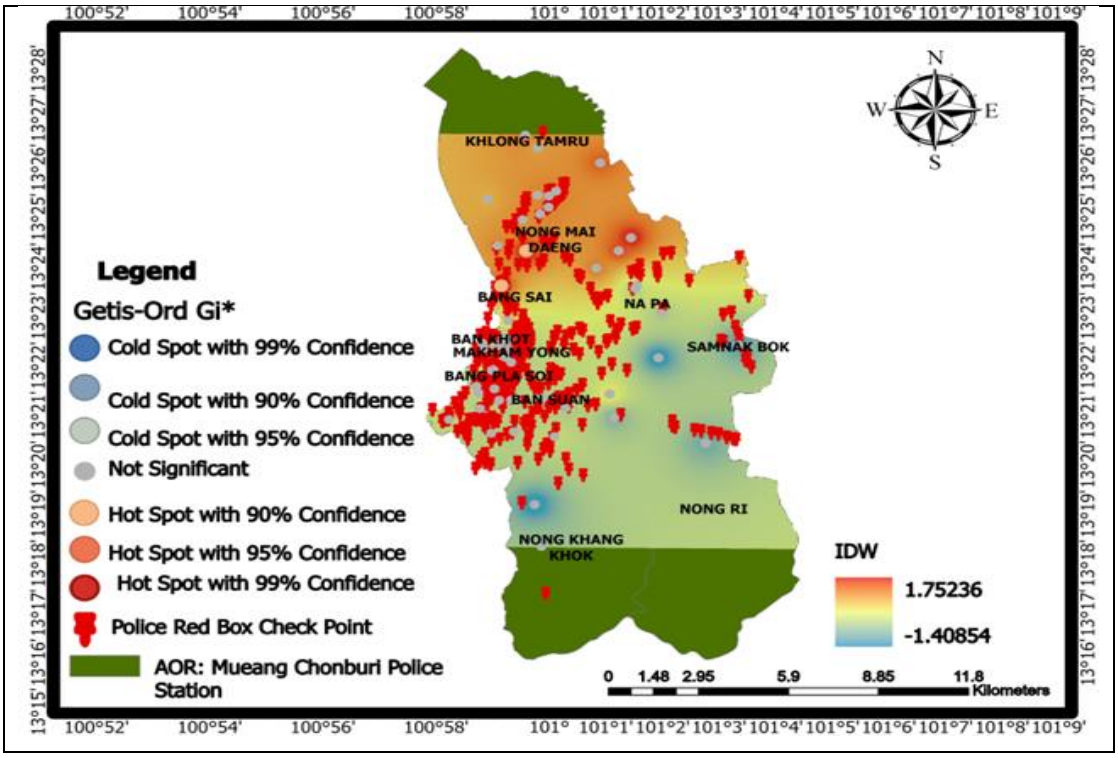


Figure 36: The relationship between risk area Nong Mai Daeng and police red box checkpoints in 2021.

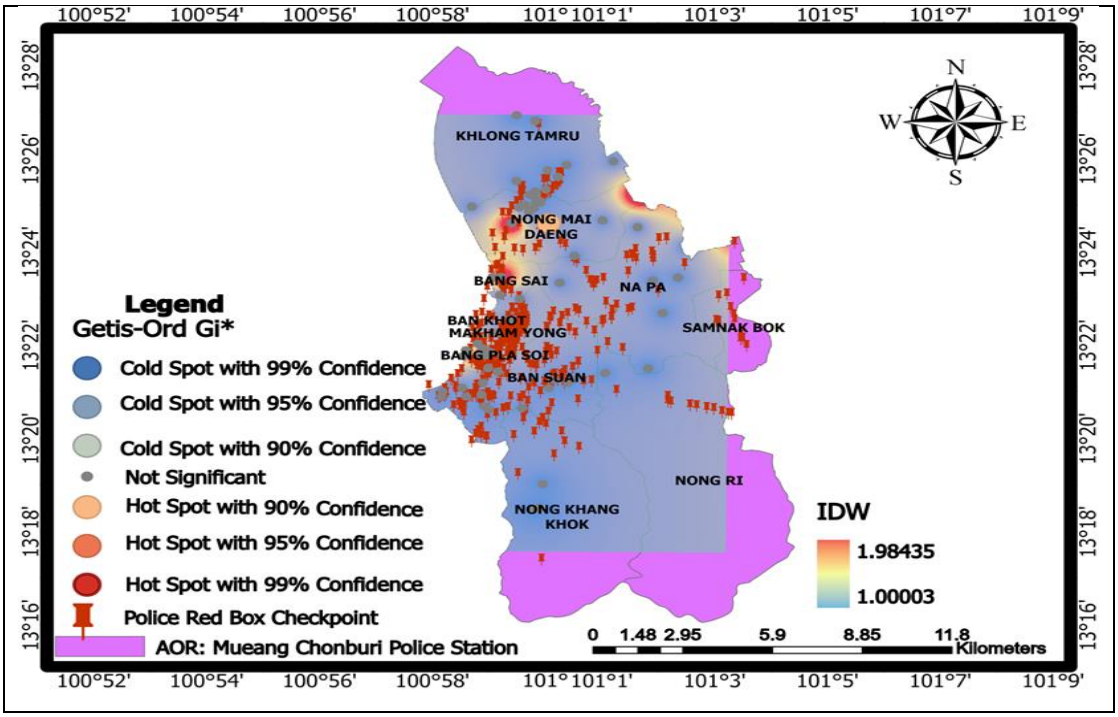


Figure 37: The relationship between risk area Nong Mai Daeng and police red box checkpoints in 2022.

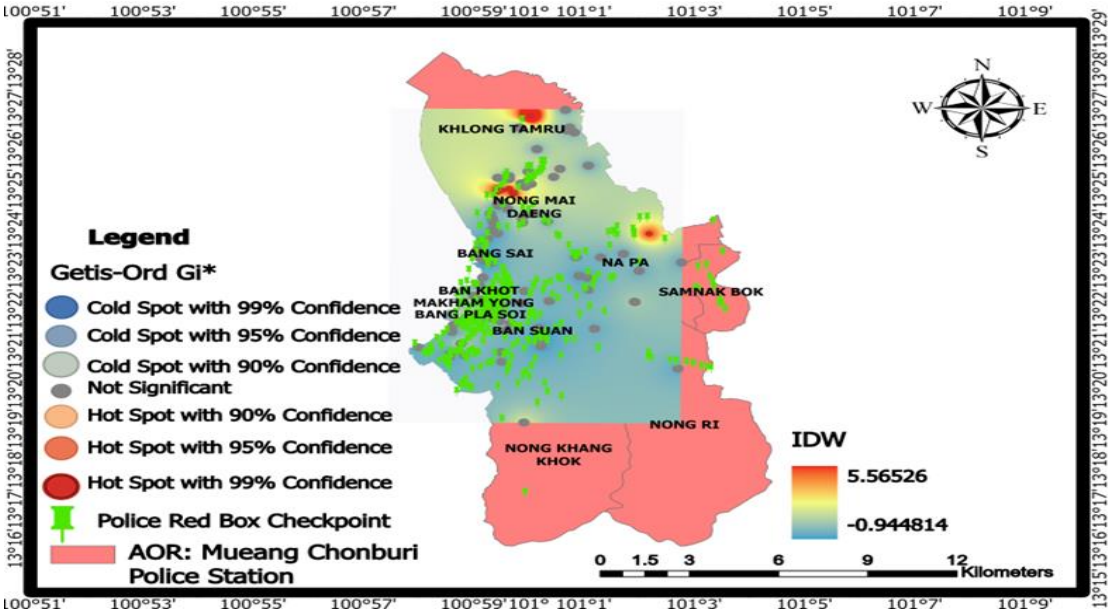


Figure 38: The relationship between risk area Nong Mai Daeng and police red box checkpoints in 2023.

The results show that the quantity of police red box checkpoints in the high-risk area of Nong Mai Daeng is lower compared to other areas with lower crime rates, such as Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong. Due to the land use types in Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong, which primarily consist of commercial establishments, particularly gold shops, is required to conduct patrols by the police. The areas of Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong have approximately 50 gold shops. For security purposes, the majority of gold merchants are equipped with police red box checkpoints. Therefore, in these areas, the presence of police red box checkpoints is more pronounced compared to the Nong Mai Daeng zone.

4.1.5 The Correlation between Risk Areas and Land Use

The criminology theories such as rational choice theory, routine activity theory, and crime pattern theory explain how the environment or spatial context impacts the distribution of crime occurrence. The spatial association between crime incidents and their surrounding environment is always a hot issue in environmental criminology for understanding crime occurrence[48]. This section of the study will examine the similar results of risk areas while employing three different methods: Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE). Additionally, the study

will overlay risk areas with land use to investigate the potential association between risk areas and land use. Furthermore, this research will examine the relationship between land use within the surrounding zone of high-risk areas, as well as investigate the disparity in land use between the highest-risk areas and the lowest-risk areas.

According to the findings shown in Table 7, the outcomes of the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) methods, in 2019 indicates that crime hotspots were predominantly located in Nong Mai Daeng. These hotspots were characterized by high, very high, and very high-risk locations for stolen motorbikes, respectively. In the year 2019, there were a total of 55 instances of motorbike theft. The land-use type flats, room for rent, had the highest number of crime incidences, with 21 cases. Private dwellings had 13 cases, while market, shop, and department stores had 7 cases. 4 Cases involving institutional land. There are 10 cases for other land use kinds, such as roadways and car parks.

In 2020, The results obtained from the Kernel Density Estimation (KDE) algorithm can forecast areas of risk. The result shows that Nong Mai Daeng is at very high risk of stolen motorcycles. Thailand has been affected by the COVID-19 pandemic this year. The study area had a total of 22 instances of motorbike theft, which had an impact on the outcome of the crime analysis. In 8 occurrences, the land use type private residences were the most frequented place for crime incidences. Subsequently, there were 6 instances of apartments and rooms available for rent, followed by 4 instances of markets, shops, and apartment stores. The case of institutional land 1. There are 3 cases of other land use kinds, such as streets and car parks.

Similar to the year 2021, The results obtained from the method, which incorporates the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) techniques, indicate that crime hot spots in Nong Mai Daeng are predominantly located in locations characterized by medium-risk, very high, and high-risk levels of stolen motorcycles, respectively. There exists a total of 66 cases. The biggest incidence of crime occurred in land-use type apartments, namely in rooms for rent, with 28 occurrences. Private dwellings followed closely behind with 11 cases, and institutional land also had 11 cases. The number of cases for market, shop, and

department store is 9. Regarding other land use categories such as roadways, car parks, garages, and vacant land, there are 7 instances.

In 2022, the outcomes of Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) indicate that crime hot spots were primarily located in Nong Mai Daeng, classified as medium-risk, very high, and very high-risk areas for stolen motorcycles, respectively. In the year 2022, there were a total of 78 reported instances of motorcycle theft. The locations with the highest incidence of crime were land-use-type apartments and rooms for rent, with 19 crimes reported. Market, shop, and apartment stores followed with 12 cases, Institution land with 11 cases, and private dwellings with 9 cases. Regarding other land use categories such as roadways and car parks, there are 27 instances.

In 2023, Nong Mai Daeng remains the area with the very high-risk areas, as indicated by the findings of Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE). These models anticipate that crime hot spots are concentrated in Nong Mai Daeng, making it a highly vulnerable location for stolen motorcycles. The cumulative count of motorcycle thefts in the year 2023. There is a total of 146 cases. The most prevalent location for crime incidents was land-use type apartments, specifically rooms for rent, with 63 reported cases. This was followed by market, shop, and department store, which had 26 reported cases. Institutional land had 21 reported cases, while private homes had 8 reported cases. Other land use types, such as streets, car parks, garages, and empty land, also had 28 reported cases.

Consequently, Nong Mai Daeng is identified as the most high-risk location based on the findings of a 5-year data study. All three methodologies yielded comparable findings, indicating that Nong Mai Daeng is consistently susceptible to motorcycle theft, but with varying degrees of risk. Crime events were most prevalent in land-use-type villages, such as apartments, rooms for rent, and homes. This was followed by land-use type city-town-commercial areas, including markets, supermarkets, department stores, and shops. In the third tier, there exists institutional land, encompassing various establishments such as schools, temples, fire brigade stations, bus station centers, banks, and hospitals. Thus, this study will focus on risk areas in 2023 that have been identified as very high-risk levels in Nong Mai Daeng, using the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) methods. The

risk zones in Nong Mai Daeng are overlaid with the land use in Nong Mai Daeng, as shown in Figure 39.

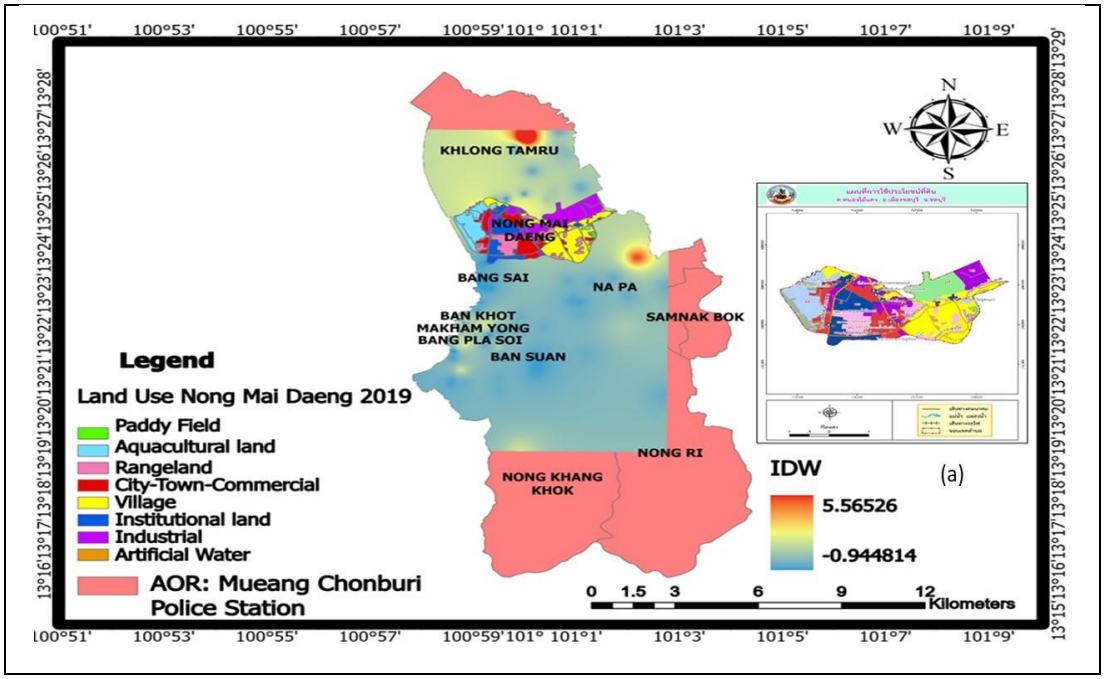


Figure 39: The overlay of risk areas 2023 and (a) land use Nong Mai Daeng.

The findings indicate that the land use in Nong Mai Daeng encompasses many categories such as city-town-commercial, industrial, village, institutional land, paddy field, rangeland, marshard swamp, miscellaneous land, communication and utility, other buildings, golf course, and natural/artificial water bodies. The city-town-commercial sections encompass an area of 1.44 square kilometers, while the village area covers 2.44 square kilometers. Additionally, the Industrial zone encompasses an area of 1.34 square kilometers. 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 AMATA City Chonburi Industrial Estate in Klong 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 5 districts and 23 subdistricts within the provinces of Chonburi and Chachoengsao. As of 31 December 2017, the factories in AMATA City Chonburi Industrial Estate employ a total of 200,000 individuals [49].

Next, this research will utilize the risk area findings from 2023, specifically focusing on Khlong Tamru by Getis-Ord Gi*, IDW, which has been identified as a very high-risk location. This study examines the overlay between risk areas in Khlong Tamru and land use categories in Khlong Tamru. Khlong Tamru is identified as the second high-risk area for motorcycles from the results of all methods each year. Due to its predominantly industrial setting in Khlong Tamru, alongside Nong Mai Daeng. The lifestyle of employees uses motorcycles for transportation in daily life and all of the 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 border areas such as Khlong Tamru and Na Pa, which consequently impact the incidence of stolen motorcycles crime in Nong Mai Daeng as presented in Figure 40.

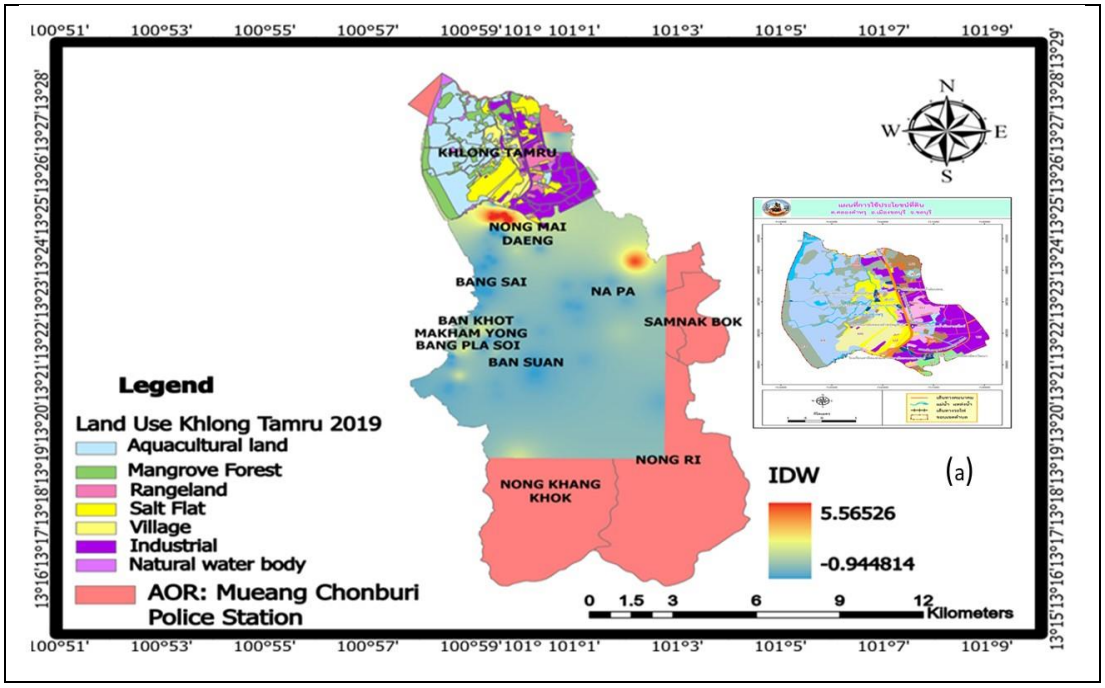


Figure 40: The overlay of risk areas 2023 and (a) land use Khlong Tamru.

According to the findings, the land use and utilization in the Khlong Tamru area encompass many categories such as industrial, village, institutional land, rangeland, marshard swamp, other miscellaneous lands, communication and utility, other buildings, golf courses, natural and artificial water bodies, and aquacultural land. The village encompasses an area of 1.92 square kilometers, while the Industrial zone spans an area of 4.58 square kilometers.

The lowest risk areas are Nong Ri, Nong Khang Kok, and Samnak Bok because of 2019 – 2023 data. There are no methods of hot spot analysis to predict the above 3 areas have risk or hot spots. Especially in Nong Ri and Samnak Bok, there are no more than 3 incidences of motorcycle theft happening in these locations each year. The lowest risk is Samnak Bok since this is the only place in 2020 and 2023 that has not experienced a stolen motorcycle crime occurrence. Although the number of crime thieves in 2023 is very high. Therefore, this research will use low-risk area in 2023 which is shown in Samnak Bok overlay with land use as presented in Figure 41.

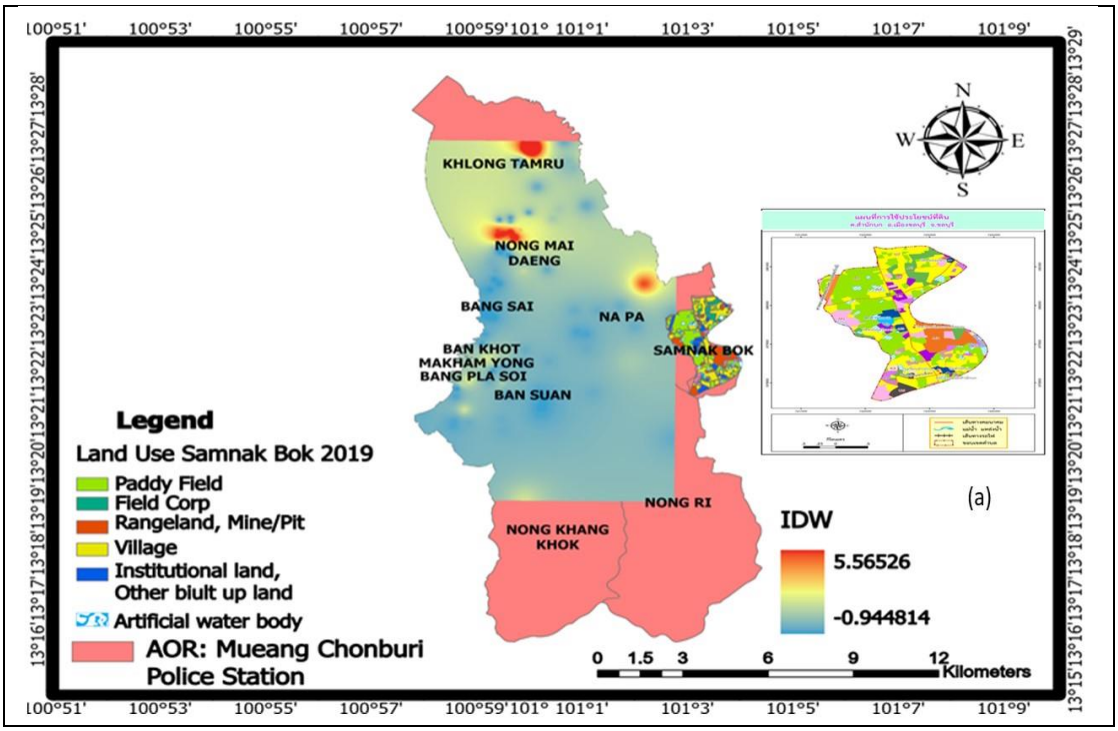


Figure 41: The overlay of low-risk area 2023 and (a) land use Samnak Bok.

The findings indicate that the majority areas of the Samnak Bok consist of paddy fields, field corp, orchards, perennial corp, deciduous forests, mine-pit, pasture

and farmhouse, rangeland, marshard swamp, natural and artificial water bodies around 3.01 square kilometers, village 1.41 square kilometers. The industrial zone covers 0.19 square kilometers. There are no commercial establishments in this region.

4.2 Comparing Stolen Motorcycles' Risk Areas Before COVID-19, During and After COVID-19

4.2.1 Pre-COVID-19 Timeframe

In 2019, the number of stolen cases amounted to 55. The majority of criminal incidences occurred in land-use type apartments, specifically in 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. 4 cases involving institutional land. For additional land use categories such as roadways and car parks, there are 10 instances. Following the analysis of crime, three areas were identified as potential risk areas, namely:

1. Nong Mai Daeng: The outcomes of Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) yield comparable forecasts indicating that crime hot spots were concentrated in Nong Mai Daeng, characterized by high, very high, and very high-risk locations for stolen motorcycles, respectively as presented in Table 7.
2. Khlong Tamru and Bang Pla Soi are the outcomes of the algorithm IDW and Kernel Density Estimation (KDE), which represent the intensity of crime in very high-risk areas as presented in Table 7.

4.2.2 COVID-19 Timeframe

In the year 2020, a total of 22 instances of motorcycle theft were documented. Thailand declared a state of emergency in response to the COVID-19 pandemic. Thailand implemented a lockdown regime for its citizens. These factors also impacted both the offenders and victims across different locations and periods. The implementation of police checkpoints is widespread throughout the region. The sole method capable of predicting risk areas in 2020 is Kernel Density Estimation (KDE). The areas of Nong Mai Daeng and Khlong Tamru exhibit a very high level of risk during the current COVID-19 period. Therefore, the risk areas are quite similar before Covid 19. Only Bang Pla Soi was shifted out from the risk areas as presented in Table 7. In 8 occurrences, the land use type private residences were the most frequented

place for crime incidences. Subsequently, there are 6 instances of apartments and rooms for rent, followed by 4 instances of markets, shops, and department stores. The case of institutional land 1. There are 3 cases for additional land use kinds, such as roadways and car parks. The majority of crime occurrences took place in private residences. As a consequence of this period, all workers returned to their hometowns in different provinces. A smaller number of employees were residing in rented offices. Individuals were unable to allocate time outdoors. Consequently, the perpetrators were rendered incapable of pilfering motorcycles from either the market or store.

4.2.3 Post-COVID-19 Timeframe

During the post-COVID period, there has been a notable change in the places with a higher risk of stolen motorbike crime. The incidence of stolen motorcycle theft has risen due to the COVID-19 pandemic, with 66 cases, 78 cases, and 146 cases reported from 2021 to 2023, respectively. An underlying factor stems from the economic recession. People are confronted with a lack of financial resources and a significant prevalence of unemployment. Following the investigation of crime, 7 areas were identified as potential risk areas, as outlined below:

1. Nong Mai Daeng: The findings from the Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) models for the period of 2021-2023 indicate a consistent pattern of crime hot spots being concentrated in the area, but with varying levels of risk. From 2021 to 2023, the Getis-Ord Gi* exhibits regions categorized as medium, medium, and very high-risk, respectively. The data from IDW indicates the very high-risk threat of motorcycle theft in Nong Mai Daeng from 2021 to 2023. The application of Kernel Density Estimation (KDE) reveals areas of high and very high risk, and very high respectively. In addition, the Emerging Hot Spot Analysis result shows a new hot spot Nong Mai Daeng in 2022 and a sporadic hotspot Nong Mai Daeng in 2023 as presented in Table 7.

2. Khlong Tamru was identified as a high-risk location by IDW in 2021 and underwent a study using Emerging Hot Spot Analysis, revealing the occurrence of a new hotspot in the area

- Bang Sai was classified as a medium-risk location by Getis-Ord Gi*, whereas IDW identified it as a very high-risk area.

- Bankhot and Makham Yong were identified as areas with a very high level of risk using Kernel Density Estimation (KDE) as presented in Table 7. Land-use type flats, room for rent, had the highest number of crime incidences, with 28 cases. Private residences had 11 crimes, followed by Institution land with 11 cases. The market, shop, and department store are comprised of 9 cases. Regarding alternative land use categories, such as roadways, car parks, garages, and vacant land, there are 7 instances. These crime incidence records indicate that crime incidents were concentrated in land-use type apartments, especially during the period when workers resumed industrial employment after the lockdown. Consequently, there was a significant increase in rental demand for these flats.

3. In 2022, The Kernel Density Estimation (KDE) model identified Khlong Tamru as an area with a very high-risk level.

- Bang Pra Soi was identified as a very high-risk area by both IDW and Kernel Density Estimation (KDE).

- The IDW has classified Bang Sai as a very high-risk level, as seen in Table 7.The majority of crime incidences occurred in land-use type apartments, specifically in rooms for rent, with a total of 19 cases. This was followed by market, shop, and department stores, which reported 12 crimes. Institutional land also saw 11 cases, while private residences reported 9 cases. For additional land use categories, such as roadways and car parks, there were 27 instances. The crime incidence statistics indicate that criminal incidents were evenly distributed across land use types of apartments and rental rooms. This is due to the resumption of industrial employment by workers resumed industrial employment after the lockdown. Consequently, there was a significant increase in rental demand for these flats.

4. In 2023, Khlong Tamru and Na Pa were identified by Getis-Ord Gi* as regions with a very high risk as seen in Table 7. The most prevalent location for crime incidents was land-use type apartments, specifically rooms for rent, with 63 reported cases. This was followed by market, shop, and department store, which had 26 reported cases. Institution land had 21 reported cases, while private homes had 8 reported cases. Other land use types, such as streets, car parks, garages, and empty land, also had 28 reported cases. The statistical data on crime incidence by land use type indicates that crime incidents have remained dispersed throughout land use types

of apartments and rental rooms. This is due to the resumption of industrial employment by workers resumed industrial employment after the lockdown. Consequently, there was a significant increase in rental demand for these flats.

4.3 Generate 3D Model for Stolen Motorcycle Crime Risk Areas by Emerging Hot Spot Analysis

4.3.1 Stolen Motorcycle Crime Risk Areas by Emerging Hot Spot Analysis

According to the crime prevention principle, both crime and the apprehension of crime diminish the overall well-being of individuals. Therefore, it is imperative for the police to proactively deter crime [8]. By the third strategic plan of the Royal Thai Police, which focuses on safeguarding individuals' lives and properties, the police station must conduct weekly crime analysis. To undergo a yearly evaluation by the Police Inspector General to enhance work performance. The third strategic plan places considerable emphasis on the involvement of crime prevention and suppression squads, sometimes known as patrol police. Therefore, conducting weekly research on hot spot crimes is crucial for promptly addressing criminal activities.

According to the findings in 2021, it was observed that two new hot spots, as seen in Figure 42, were predominantly distributed across the Khlong Tamru area. It means a location that is a statistically significant hot spot for the final time step and has never been a previously statistically significant hot spot. Two incidences of stolen motorcycles have been observed as new hot spots, occurring within one week and a distance of one kilometer.

Firstly, R3: Room for rent (unnamed), address 6 m.4 Khlong Tamru District, Mueang Chonburi City, Chonburi Province, Thailand. Following the report on 27th December 2021 at around 22.00 hrs. – 04.00 hrs. of 28th December 2021. One Honda Wave 110, blue-white was stolen.

Secondly, R4: Panee Room for rent, address 67 m.1 Khlong Tumru District, Mueang Chonburi City, Chonburi Province, Thailand. Following the report on 26th December 2021 at around 22.00 hrs. – 06.00 hrs. of 27th December 2021. One Honda Wave 110, black - gray was stolen from Panee room for rent. Within a 5-year data period, there have been no instances of stolen motorcycles crime in risk zones R3 and R4.

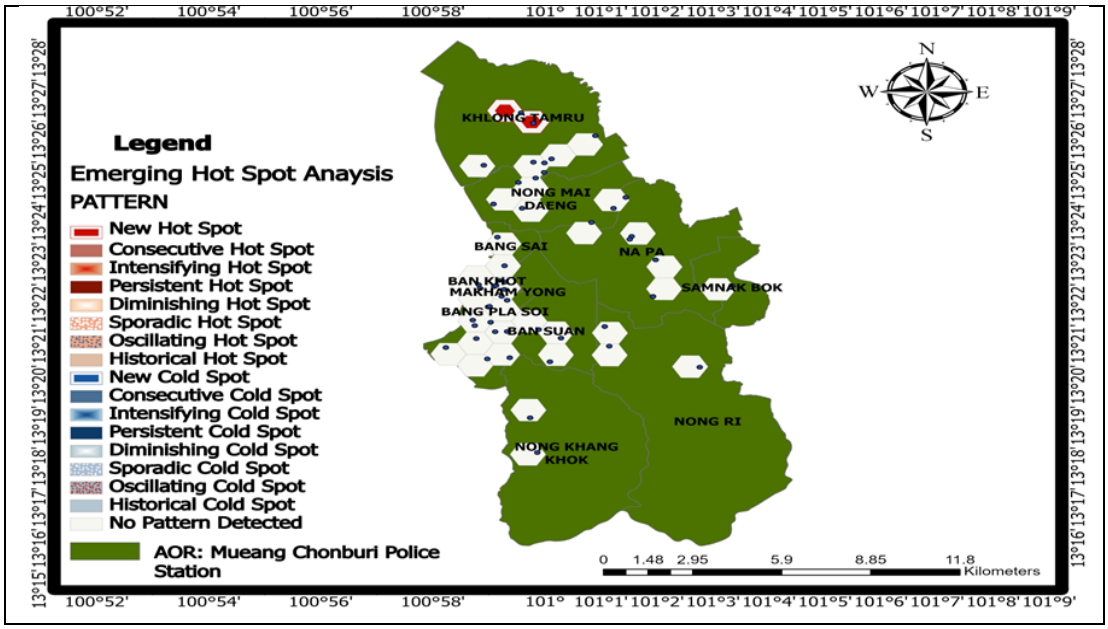


Figure 42: Emerging Hot Spot Analysis 2021.

In the year 2022, the findings indicated that two new hot spots were predominantly distributed throughout the Nong Mai Daeng area, as depicted in Figure 43. It means a location that is a statistically significant hot spot for the final time step and has never been a previously statistically significant hot spot. Two incidences of stolen motorcycles have been observed as new hot spots, occurring within one week and a distance of one kilometer.

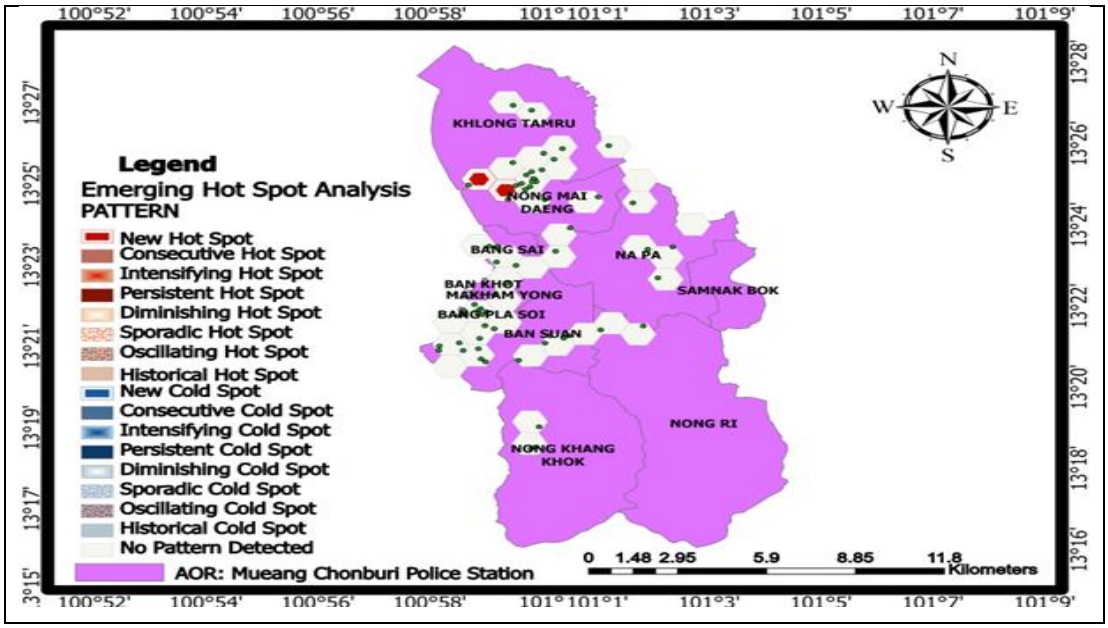


Figure 43: Emerging Hot Spot Analysis 2022.

Firstly, R1: Chonburi Bus Station, address Nong Mai Daeng District, Mueang Chonburi City, Chonburi Province, Thailand. Following the report on 1st February 2022 at around 19.00 hrs.
– 22.00 hrs. One Honda Wave 125 I, orange-black was stolen from Chonburi Bus Station. However, the stolen of motorcycles at R1 was reported again on 24th June 2022 at around 23.00 hrs. – 02.00 hrs. of 25th June 2022. One Honda Wave 110 I, blue-gray was stolen.

Secondly, R2: Ninja Market, address Nong Mai Daeng district, Mueang Chonburi City, Chonburi Province, Thailand. Following the report on 27th December 2022 at around 09.00 hrs. – 12.00 hrs. One Honda Wave 110, black-gray was stolen from Ninja Market's car park. Nevertheless, throughout 5 years, numerous instances of stolen motorcycles were reported in Ninja market locations, as outlined below.

1. In 2019, following the report on 2nd June 2019 at around 18.50 hrs. – 12.00 hrs., one Honda Wave 110, black-gray was stolen.
2. In 2020, following the report on 27th February 2020 at around 20.00 hrs. – 22.00 hrs., one Yamaha was stolen.
3. In 2021, following the report on 28th January 2021 at around 19.00 hrs. – 20.00 hrs., one Yamaha was stolen from Ninja Market's car park. on 5th February 2021 at around 20.30 hrs. – 12.00 hrs., one motorcycle was stolen.
4. In 2023, following the report on 27th January 2023 at around 18.00 hrs. – 20.00 hrs., one Honda Wave was stolen. Then at around 20.00 hrs. – 22.00 hrs., one Yamaha was stolen. Following the report on 6th May 2023 at around 20.00 hrs. – 23.59 hrs., one Yamaha was stolen. On 31st August 2023, one Yamaha was stolen.

In 2023, the results show the sporadic hot spots mainly scattered in the Nong Mai Daeng area as presented in Figure 44. It means a location that is an on-again off-again hot spot. Fewer than 90% of the time-step intervals have been statistically significant hot spots and none of the time-step intervals have been statistically significant hot spots. Occurring within one week and a distance of one kilometer.

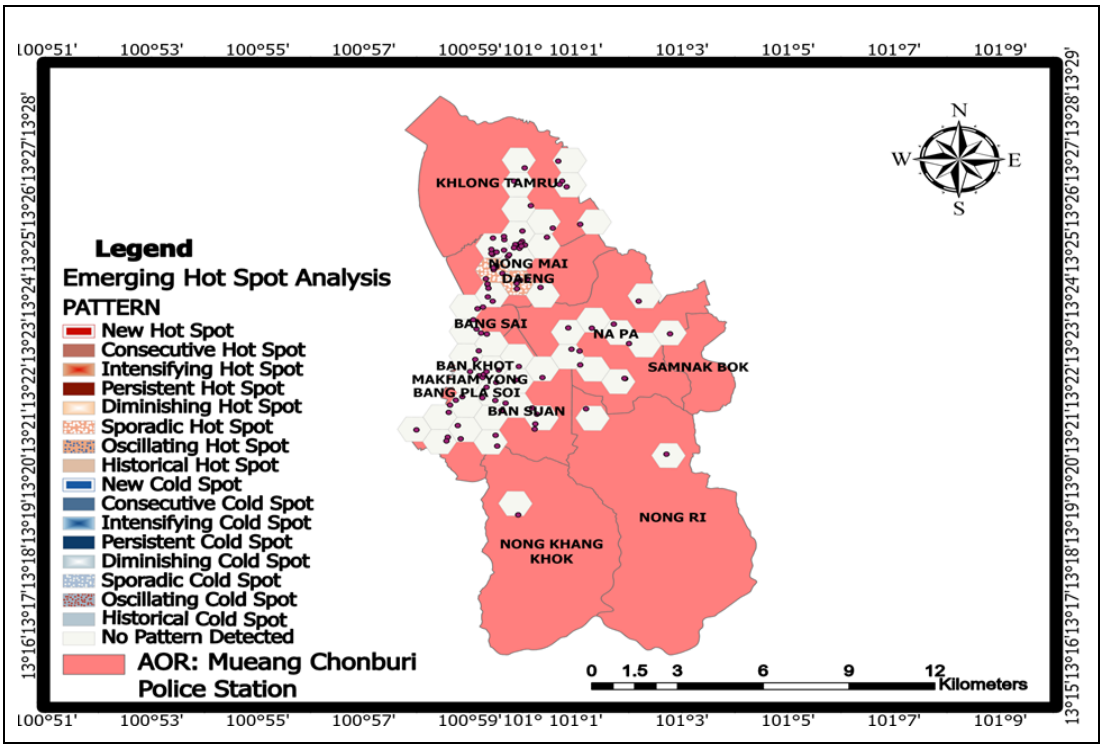


Figure 44: Emerging Hot Spot Analysis 2023

4.3.2 UAV Data Processing as Photo-Generated 3D Model of New Hot Spot Risk Areas, 2021

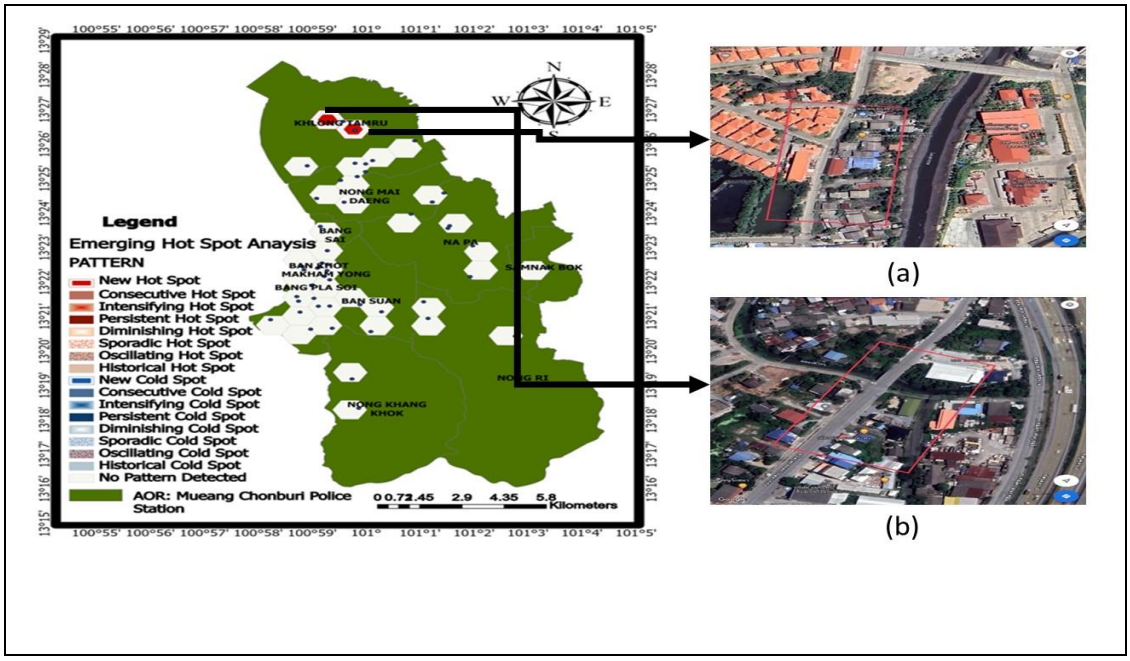


Figure 45: Two risk areas as new hot spot 2021: (a) Room for rent(unnamed); (b) Panee room for rent.

Room for rent (unnamed), Khlong Tamru District: R3

The case reported: Room for rent (unnamed) address 6 m.4 Khlong Tamru District, Mueang Chonburi City, Chonburi Province, Thailand, the location of the crime incident as shown in Figure 45(a). Following the report on 27th December 2021, at around 22.00 hrs. – 04.00 hrs. of 28th December 2021. One Honda Wave 110, blue-white was stolen from an unnamed room for rent. The photos of the crime incident as shown in Figure 46. The calibration of all 125 photos was performed using Get3D Cloud, resulting in a three-dimensional model presented in Figures 47, and 48.

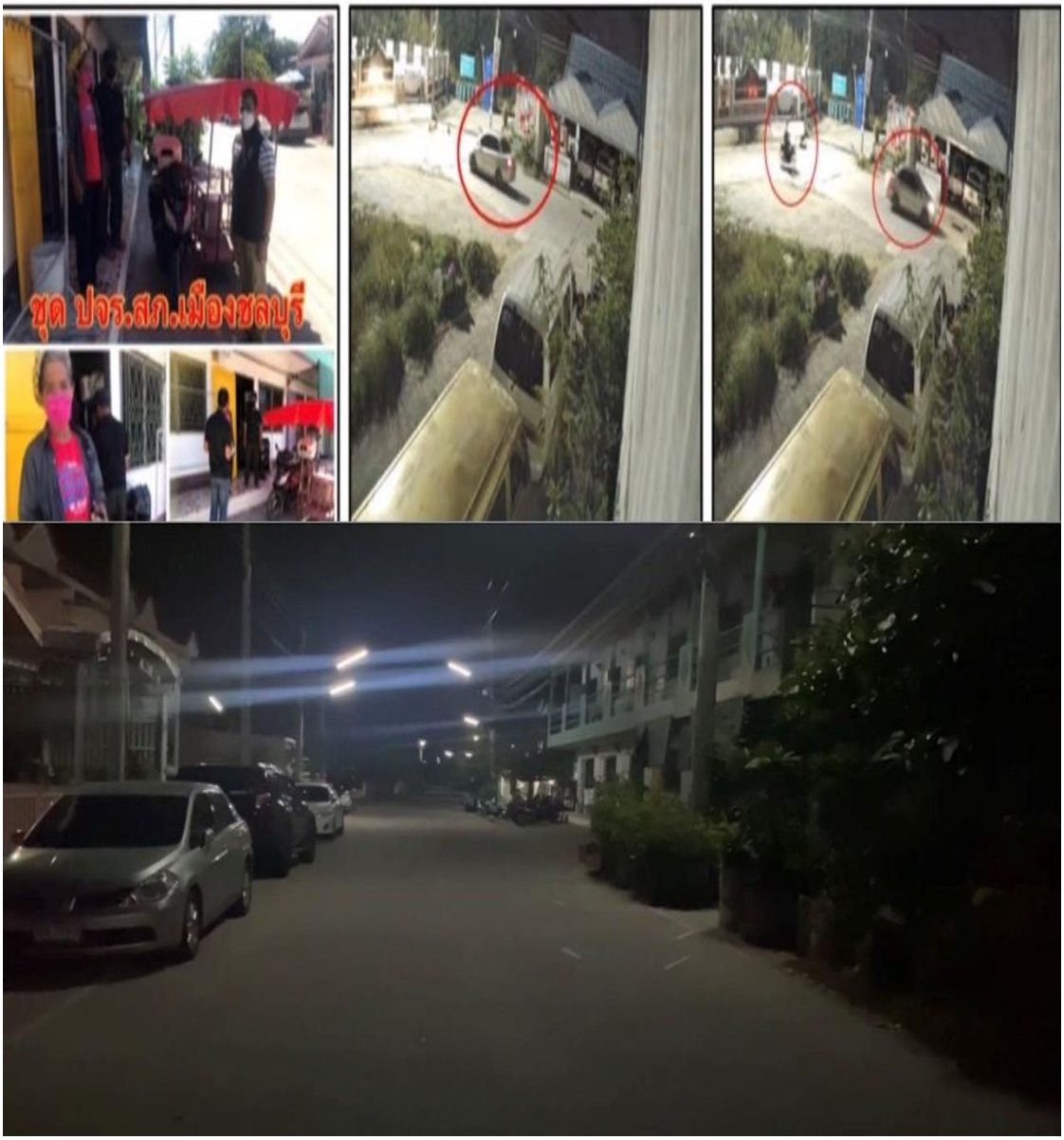


Figure 46: Location of crime incident: Room for rent (unnamed), Khlong Tamru.

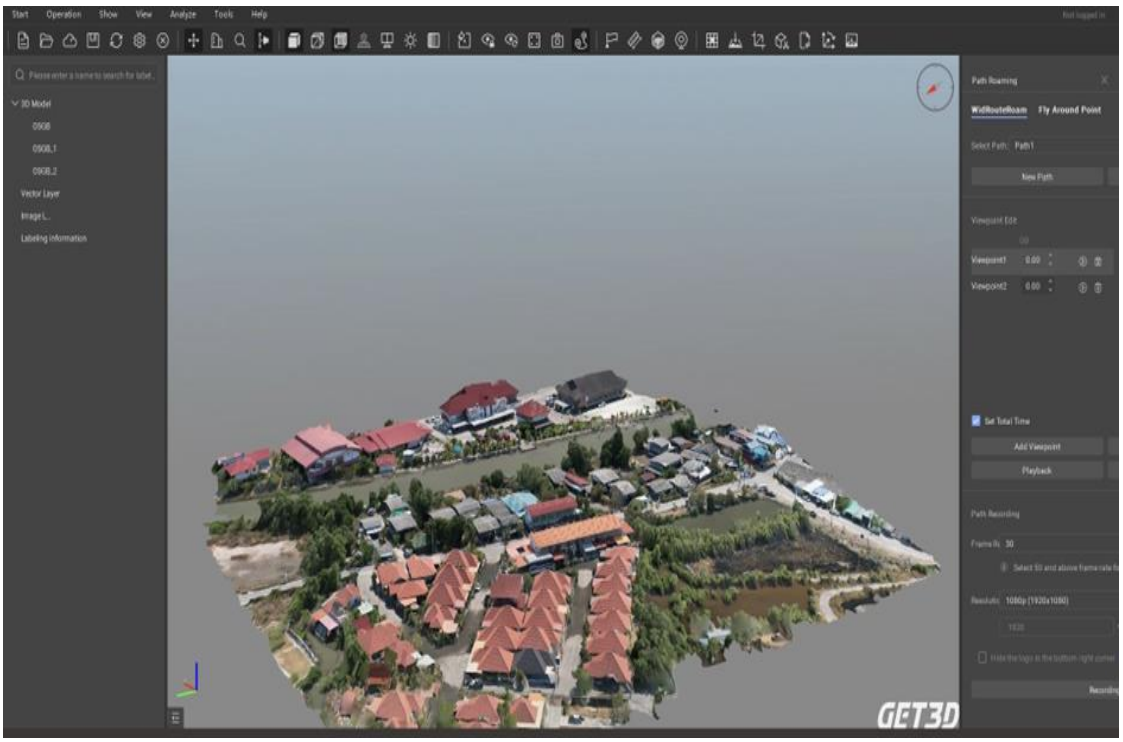


Figure 47: Photo-generated 3D model: Incident area room for rent (unnamed), Khlong Tamru.

Figure 48: Photo-generated 3D model: Incident area room for rent (unnamed), Khlong Tamru.

In the year 2021, a total of 66 incidents of stolen motorcycle crime were recorded. This location of room for rent (unnamed) has recently become a new hot spot pattern due to the Emerging Hot Spot Analysis. In terms of police policy, crime prevention plays a crucial role in combating and halting criminal activities. Therefore, to prevent the escalation of crime in the areas, it is imperative to do a comprehensive examination of the recent criminal incident. Before commencing their responsibilities, patrol police officers must possess a complete grasp of crime hot spots and their physical characteristics. The presence risk areas of stolen motorcycles pose a potential risk to patrol police during their patrolling duties. This location lacks a police red box checkpoint, and the land use in the Khlong Tamru area encompasses various categories such as an industrial, village, institutional land, rangeland, marshard swamp, other miscellaneous lands, communication and utility, other built, golf course, natural and artificial water bodies, and aquacultural land. The village encompasses an area of 1.92 square kilometers, while the industrial zone spans an area of 4.58 square kilometers. Drone photogrammetry will be employed to gather photographs of a new hot spot room for rent (unnamed) to gain a deeper understanding of the crime environment. The photo-generated 3D model reveals that the rented room is situated adjacent to the main road, approximately 3 meters away, which is commonly utilized for transportation purposes. There is no fence surrounding the rented room. The land surrounding the incident consists of villages and undeveloped land. The location lacks CCTV surveillance but has sufficient illumination during nighttime hours.

Panee room for rent, Khlong Tamru District: R4

The case reported: Panee room for rent address 67 m.1 Klong Tamru District, Mueang Chonburi City, Chonburi Province, Thailand, the location of the crime incident as shown in Figure 45 (b). Following the report on 26th December 2021, at around 22.00 hrs. – 06.00 hrs. of 26th December 2021. One Honda Wave 110, black - gray was stolen from Panee room for rent. The photos of crime incidents as shown in Figure 49. The calibration of all 101 photos was performed using Get3D Cloud. The outcome of a photo-generated three-dimensional model is depicted in Figures 50, and 51.

Figure 49 : Location of crime incident: Panee room for rent, Khlong Tamru.

Figure 50: Photo-generated 3D model: Incident area Panee room for rent, Khlong Tamru.

Figure 51: Photo-generated 3D model: Incident area Panee room for rent, Khlong Tamru.

There were a total of 66 incidents of stolen motorcycles in 2021. The analysis of Emerging Hot Spot Analysis has identified this area of Panee room for rent as a new hot spot pattern. There is no police checkpoint in this location. The land use in the Khlong Tamru area includes the industrial, village, institutional land, rangeland, marshard swamp, other miscellaneous lands, communication and utility, other built, golf courses, natural and artificial water bodies, and aquacultural land. The village area measures 1.92 square kilometers, while the Industrial zone encompasses 4.58 square kilometers. Drone photogrammetry will be employed to gather photographs of the new hot spot Panee room for rent to gain a deeper understanding of the crime environment. The photo-generated 3D model indicates that this rental room is situated adjacent to the major road and near Sukhumvit Rd, which is frequently utilized for transit purposes. There is no fence surrounding the rented room. There are a total of ten rooms available for rental. The land use surrounding the incident encompasses villages, unoccupied property, and government agencies. The location lacks CCTV surveillance but has sufficient illumination during nighttime hours.

4.3.3 UAV Data Processing as Photo-Generated 3D Model of New Hot Spot Risk Areas, 2022

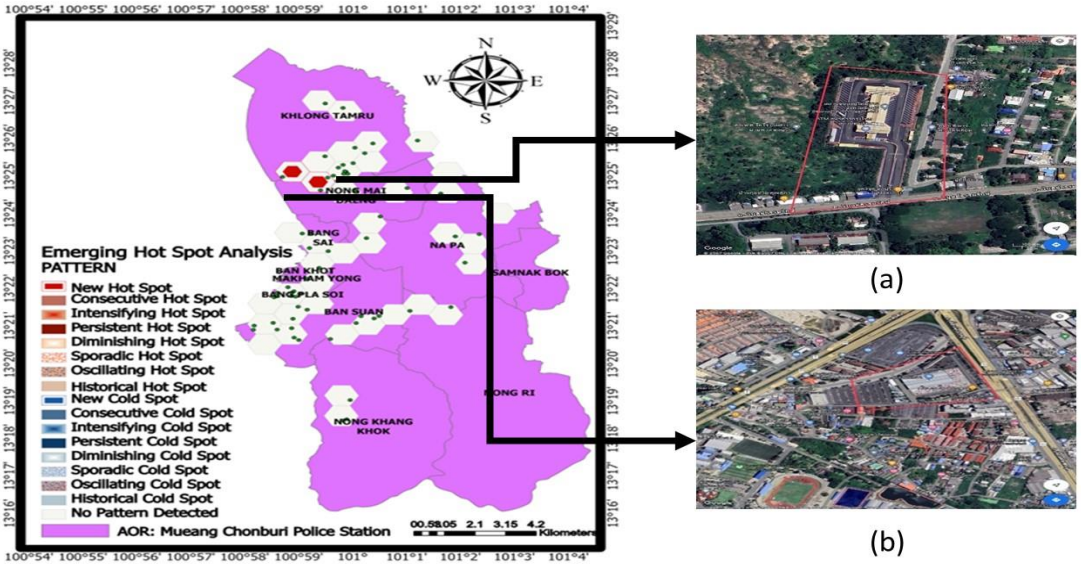


Figure 52: Two risk areas as new hot spot 2022: (a) Bus Station; (b) Ninja Market.

Chonburi Bus Station, Nong Mai Daeng District: R1

The case reported: Chonburi Bus Station, address Nong Mai Daeng District, Mueang Chonburi City, Chonburi Province, Thailand, the location of the crime incident as shown in Fig. 52 (a). Following the report on 1st February 2022 at around 19.00 hrs. – 22.00 hrs., one Honda Wave 125 I, orange-black was stolen from Chonburi Bus Station. The photos of the crime incident as shown in Figure 53. All the 214 images were calibrated by Get3D Cloud. The outcome of a photo-generated three-dimensional model is depicted in Figure 54, and 55.

Figure 53: Location of crime incident: Bus station, Nong Mai Daeng.

Figure 54: Photo-generated 3D model: Incident area Bus station, Nong Mai Daeng.

Figure 55: Photo-generated 3D model: Incident area Bus station, Nong Mai Daeng.

There were 78 stolen motorcycles crime in 2022. The analysis of Emerging Hot Spot Analysis has identified this area of the Bus station as a new hot spot pattern. There is no police checkpoint in this location. The land use in the Nong Mai Daeng area includes the city-town-commercial, industrial, village, institutional land, paddy field, rangeland, marshard swamp, another miscellaneous land, communication and utility, other built, golf courses, natural and artificial water bodies. The area allocated for the city-town-commercial area is 1.44 square kilometers, for the village, it is 2.44 square kilometers, and for the industrial zone, it is 1.34 square kilometers. Drone photogrammetry will be employed to gather photographs of the new hot spot Bus station to gain a deeper understanding of the crime environment. The photo-generated 3D model reveals that the bus station encompasses a substantial expanse situated adjacent to unoccupied land, military facilities, and sparsely populated areas. Sufficient illumination during nighttime and the presence of closed-circuit television (CCTV) systems are also present in this vicinity. There is only one way to enter and exit the location.

Ninja Market, Nong Mai Daeng District: R2

The case reported: Ninja Market, Nong Mai Daeng district, Mueang Chonburi City, Chonburi Province, Thailand, the location of the crime incident as shown in Figure 51 (b). Following the report on 27th December 2022 at around 09.00 hrs. – 12.00 hrs. One Honda Wave 110, black-gray was stolen from Ninja Market's car park. The photos of the crime incident as shown in Figure 56. All the 213 images were calibrated by Get3D Cloud. The outcome of a photo-generated three-dimensional model is depicted in Figure 57, and 58.

Figure 56: Location of crime incident: Ninja market, Nong Mai Daeng.

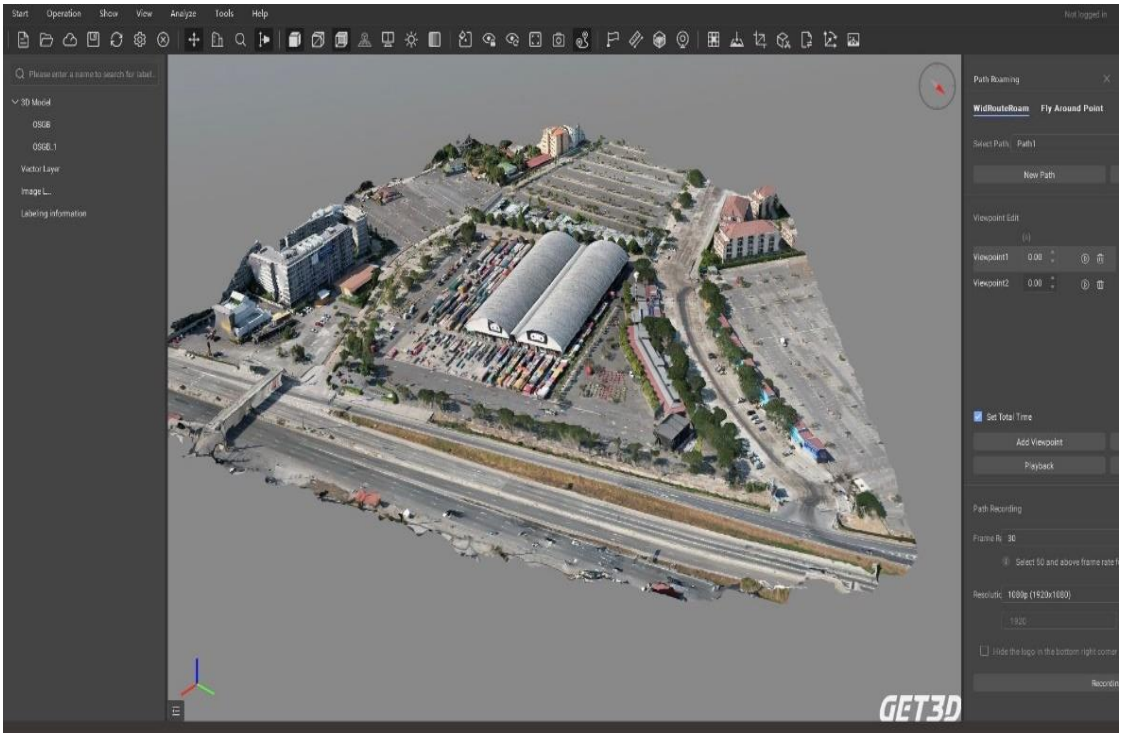


Figure 57: Photo-generated 3D model: Incident area Ninja market, Nong Mai Daeng.

Figure 58: Photo-generated 3D model: Incident area Ninja market, Nong Mai Daeng.

In 2022, there were a total of 78 incidents of stolen motorcycles. The analysis of Emerging Hot Spot Analysis has identified this area of Ninja market as a new hot spot pattern. This location lacks a police red box checkpoint, and the land use in the Nong Mai Daeng area encompasses various categories such as a city-town-commercial, industrial, village, institutional land, paddy field, rangeland, marshard swamp, other miscellaneous lands, communication, and utility, other built, golf course, and natural and artificial water body. The city-town commercial districts cover an area of 1.44 square kilometers, the village covers an area of 2.44 square kilometers, and the industrial zone covers an area of 1.34 square kilometers. Drone photogrammetry will be employed to gather photographs of the crime-prone environment of Ninja market to gain a deeper understanding of it. The outcome of the photo-generated three-dimensional model indicates that the market encompasses a substantial expanse. The land use consists of residential neighborhoods and large car parking zones. There is plenty of illumination during the night and surveillance cameras in that vicinity. There are six methods to enter and exit the location.

4.4 Promoting the use of e-bikes among motorcycle riders in Thailand by learn from China's experience in adopting e-bikes.

Based on Right Realism/Rational Choice Theory proposed by Beccaria (1995) and Bentham (1843). Bentham wrote that the incentive for criminal behavior is the financial gain derived from the crime, whereas the deterrent effect is the pain caused by the punishment. If the first of these forces is greater profits, the criminals will commit a crime; if the second, the criminals will not commit a crime [6]. Shanghai began annual inspections of gasoline-powered scooters, eliminating those of which exhaust gas emission was unacceptable- 53,000 were eliminated in 1999-Mayor states a desire to replace all motor scooters with electric bikes in the next 4-5 years.

4.4.1 The transition to electric bikes in China

China produces a vast array of electric bike types, numbering in the hundreds. The majority of electric bikes can be classified as either bicycle-style electric bikes (BSEB) or scooter-style electric bikes (SSEB). Most electric bike styles can be categorized into a spectrum of three styles that lie between these two sorts. The SSEBs has numerous characteristics similar to those of gasoline-powered scooters, including

horns, headlights, brake lights, turn signals, and speedometers. The majority depend only on electric power, rather than human pedaling. BSEBs closely resemble regular bicycles in both form and function, including the presence of functional pedals.

The technology employed in each variant of electric bicycles is comparable. An electric battery consists mostly of a hub motor, controller, and battery. Typically, BSEBs are equipped with batteries that have a voltage of 36V and motors with a power output ranging from 180W to 250W. SSEBs generally include larger 48V batteries and more powerful motors, typically ranging from 350 to 500W. Electric bikes are subject to regulations that restrict their maximum speed to 20km/hr. However, it is common for many electric scooters to surpass this limit and some are even advertised to reach speeds of 40km/hr. Electric bicycles can travel a distance of 40-50 kilometers on a single charge. Electric bikes are typically permitted to use the bicycle lane in most cities and are classified as bicycles according to regulations. Therefore, there is no requirement for helmets or driver's licenses. An outstanding advantage of using e-bikes is that there is no need for additional infrastructure to recharge them. Charging can be achieved by connecting to a regular electrical socket. Most e-bike riders surveyed recharge their e-bikes at home during the night when electricity rates are lower. In metropolitan locations, this commonly refers to a multi-storey apartment complex, necessitating the user to transport the bike battery indoors for the purpose of recharging. It is frequently observed that bicycles are being recharged during daytime outside ground-floor establishments using regular electrical outlets. The Chinese electric bike market has experienced exponential growth in the past five to seven years, with production increasing from over 40,000 units in 1998 to over 10 million units in 2005. The advancements in battery and motor technology since the 1990s have played a crucial role in the expansion of the e-bike business. Electric bicycles, capable of achieving distances of 50-60 kilometers and equipped with motors ranging from 250 to 350 watts, have already reached a level of performance that can rival that of traditional gasoline-powered scooters. The two e-bike components that have seen significant technological advancements are the lead-acid batteries and the in-hub wheel e-bike motors. The primary economic drivers behind the swift adoption of e-bikes in China are the increasing disposable income of the Chinese population, the declining expenses

associated with e-bike technology, and the escalating prices of gasoline. The pricing range for e-bikes is as follows: premium e-bikes, which cost more than 2600 RMB, are primarily SSEB models with a few high-quality BSEB options. Moderate e-bikes, priced between 1800 and 2200 RMB, are available in both BSEB and SSEB models. Economical e-bikes are simple BSEB models.

National standards for electric bicycles In 1999, national guidelines were implemented to define performance thresholds for e-bikes in terms of speed, weight, and power. An essential need in the specification was that a bike may be categorized as an e-bike as long as it had operational pedals. This classification enabled SSEBs to be governed by the same laws and regulations as BSEBs. This particular provision of the standard had the impact of creating a vast and significant market opportunity for SSEBs.

Legislation on National Road Transportation Safety The Road Transportation Safety Law, which was drafted in 2000 and adopted in 2004, categorizes e-bikes as a non-motorized vehicle, thereby granting them same rights to bicycles. This legislation not only grants riders the privilege of riding in the designated bicycle lane, but also confers legal authority onto e-bike advocates in both the industry and government to defend the usage and sale of e-bikes in numerous urban areas [50].

4.4.2 Stolen E-Bikes in Jianghan District, Wuhan City, China

Jianghan District, located in Wuhan, benefits from its strategic location and excellent transportation infrastructure, making it the city's primary hub for business activities. The city boasts a prosperous commercial and financial sector, with three distinct business hubs located in the eastern and southern regions. Additionally, it has a robust service industry and a well-established manufacturing sector. Jianghan District is equipped with several public amenities, including parks, river beaches, pedestrian pathways, and public squares. Nevertheless, it is undergoing significant urbanization. There are currently five urban settlements located in the northern and western regions. Additionally, there is a significant construction project underway in the western area. The intricate economic and physical features of Jianghan District contribute to a significant incidence of criminal activity. According to the Wuhan Municipal Bureau of Public Security, there were 1594 instances of electric bicycles being stolen between

January 1, 2013, and August 31, 2013 [51]. In 2018, the municipality of Wuhan, situated in Central China, introduced its own iteration of the Internet of Things (IoT) to reduce the frequency of theft events involving electric bicycles owned by its people. Wuhan successfully implemented its Internet of Things (IoT) network by integrating smart chips into a fleet of 560,000 electric bicycles, resulting in complete coverage of the city. There has been a 40 percent decrease in the number of currently missing e-bikes compared to the previous year [52].

4.4.3 An Anti-Theft Electric Bicycle Tracking System

An electric bicycle is a prevalent mode of transportation in China. An anti-theft electric bicycle tracking system (ATEBTS) was developed to enhance bicycle safety for large-scale users. This system tracks electric bicycles by collecting and analyzing data on their states and running conditions. This system utilizes a microprocessor equipped with embedded Global Positioning System (GPS) modules in bicycles to transmit data in real-time via General Packet Radio Service (GPRS) and Global System for Mobile Communication (GSM). Additionally, an internal G sensor is capable of retrieving real-time state information, including acceleration and shaking signals. The system implemented a message protocol to package and transmit this data to servers. It also utilized a distributed architecture, which included clusters for the OpenFire server, cache queue, database, and web server [53].

The Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) models have identified Nong Mai Daeng District as the highest risk of motorcycle theft. The outcomes of the three approaches yielded comparable forecasts for the period from 2019 to 2023, with a particular focus on identifying Nong Mai Daeng as a risk area at varying levels: medium, high, and very high. The Khlong Tamru neighborhood is the second most vulnerable to motorcycle theft. During the period spanning from 2019 to 2023. These results are supported by the results of the Emerging Hotspot Analysis show that Nong Mai Daeng and Khlong Tamru are new hot spots in 2021 and 2022. The results show Nong Mai Daeng as sporadic hot spot in 2023.

CHAPTER NO 5: DISCUSSION AND CONCLUSION

5.1 Discussion

The Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) models have identified Nong Mai Daeng District as the highest risk of motorcycle theft. The outcomes of the three approaches yielded comparable forecasts for the period from 2019 to 2023, with a particular focus on identifying Nong Mai Daeng as a risk area at varying levels: medium, high, and very high. Even though the COVID-19 period has identified Nong Mai Daeng as the location with the highest risk, as determined by Kernel Density Estimation (KDE). The KDE approach is the sole means of forecasting risk areas in 2020 due to the limited number of 22 crime cases recorded this year. Alternatively, there exists an alternative approach that firmly affirms Nong Mai Daeng's classification as a highly vulnerable area and emphasizes the need for prompt action to mitigate the occurrence of stolen motorcycles in this area. In 2022, the Emerging Hotspot Analysis revealed the presence of two new hot spots whereas in 2023, sporadic hotspot patterns were seen in Nong Mai Daeng. The data for 2019 and 2020 cannot be analyzed using Emerging Hotspot Analysis because the number of instances is below 60.

Nong Mai Daeng has a lesser number of police red box checkpoints compared to lower-risk areas such as Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong. The density of the population in Nong Mai Daeng is substantial. Moreover, the Nong Mai Daeng District serves as a significant economic center for a substantial population. A significant proportion of the population migrates to the area in search of employment opportunities. The land use in Nong Mai Daeng encompasses many categories such as city-town-commercial, industrial, village, institutional land, paddy field, rangeland, marshard swamp, miscellaneous land, communication and utility, other buildings, golf courses, and natural and artificial water bodies. The city-town-commercial districts cover an area of 1.44 square kilometers, the villages cover an area of 2.44 square kilometers, and the Industrial zone covers an area of 1.34 square kilometers. Furthermore, Nong Mai Daeng experienced the impact of the neighboring district of Khlong Tamru, which is identified as the second most vulnerable location for motorcycle theft.

The Khlong Tamru neighborhood is the second most vulnerable to motorcycle theft. During the period spanning from 2019 to 2023, Khlong Tamru was consistently a high-risk area. In 2019, the maximum two approaches IDW and Kernel Density Estimation (KDE) identified Khlong Tamru as a very high-risk area, whereas in 2023, Getis-Ord Gi* and IDW identified Khlong Tamru as a very high-risk area. Although the COVID-19 period has identified Khlong Tamru as the location with the highest risk, as determined by Kernel Density Estimation (KDE). The only method capable of predicting risk zones in 2020 is KDE. Nevertheless, an alternative approach asserts that Khlong Tamru is classified as a risk area and necessitates prompt action to mitigate the occurrence of stolen motorcycles in this area. The Emerging Hotspot Analysis revealed the emergence of two new hot spots in 2021. The data for the years 2019 and 2020 is not suitable for analysis using Emerging Hotspot Analysis because of the limited number of cases, which is fewer than 60.

Khlong Tamru exhibits a lesser quantity of police red box checkpoints compared to other areas with lower risk levels, such as Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong. The population in Khlong Tamru is substantial. Moreover, the Khlong Tamru District serves as the primary industrial center for Amata Industrial. The land use in the Khlong Tamru area encompasses several categories such as industrial, village, institutional land, rangeland, marshard swamp, other miscellaneous lands, communication and utility, other buildings, golf courses, natural and artificial water bodies, and aquacultural land. The village encompasses an area of 1.92 square kilometers, while the industrial zone spans an area of 4.58 square kilometers. In some years, certain methodologies have classified Bang Sai, Bang Pla Soi, Bankhot, Makham Yong, and Na Pa as posing medium, high, and very high levels of risk.

This study will specifically concentrate on the locations of Nong Mai Daeng and Khlong Tamru, which have been identified as high-risk due to the evident outcomes obtained from various methodologies. Furthermore, there are potential advantages to directing crime prevention initiatives towards crime-prone areas. Crime is concentrated in tiny areas, known as "hot spots," which account for 50% of all criminal incidents. if law enforcement authorities direct their attention towards these aberrant locations. If the police can proactively deter crime in these areas of high

activity, they may be able to effectively decrease overall crime rates while utilizing limited resources in a select few locations with high crime rates [4].

An advantage of Emerging Hot Spot analysis, which sets it apart from the other three methodologies, is its temporal characteristics. A space-time cube model was presented to find cold/hot spots using EHAM. This study aims to analyze the temporal and spatial dynamics of 17 spatiotemporal evolution modes, focusing on their patterns and trends. To promptly address incidents of stolen motorcycle crime, the EHAM system is employed to monitor emerging hot spots within a weekly timeframe and a radius of 1 kilometer. According to the findings, it is evident that in the year 2021, room for Rent (unnamed) and Panee room for rent were weekly new hot spots in Khlong Tamru. In the year 2022, the Bus station and Ninja market were weekly new hot spots in Nong Mai Deang.

Drone photogrammetry technique by a low-cost UAV (DJI AIR 2s) was used to capture the images of a small section of risk areas for operation planning such as patrol planning, tactical training planning, and community policing planning. With no GCP (direct georeferencing; using only UAV onboard sensor information without RTK/PPK solutions). UAVs offer several advantages over manned photogrammetry such as UAVs are low-cost and can work so fast to obtain data. Within 1 hr., around 760 images were captured from 4 risk areas R1: Chonburi Bus Station, R2: Ninja market, R3: Room for rent (unnamed), R4: Panee room for rent. The flight covers 4 risk areas: R1 of 0.016 square kilometers, area R2 of 0.016 square kilometers, area R3 of 0.0016 square kilometers, and area R4 of 0.0032 square kilometers. The next process is a Photo-generated 3D model by Get3D Cloud.

The findings from a 5-year analysis of crime. The land-use village, which includes apartments, room for rent, and homes, experienced the highest incidence of criminal occurrences. This was followed by land-use type city-town-commercial, which includes markets, supermarkets, department stores, and shops. Institutional land, encompassing educational institutions, religious sites, fire brigade stations, bus station centers, banks, and hospitals, occupies the third position. The risk areas R3 - R4 pertain to the land use category of the village, specifically encompassing flats and rooms for rent in Khlong Tamru. R1: The bus station in Nong Mai Daeng is classified as institutional land. Risk area R2: The Ninja market in Nong Mai Daeng is classified

as a land use type categorized as city-town-commercial. The 3D model built by Get3D Cloud demonstrates as follows:

R1: The Bus Station in Nong Mai Daeng is situated on expansive territory adjacent to a military facility. The area surrounding the bus station is sparsely populated, providing ample illumination during nighttime. Additionally, the region is equipped with closed-circuit television (CCTV) surveillance. The location can only be accessed and departed from in one way. There is a lack of police red box checkpoints in R1.

R2: The Ninja market, Nong Mai Daeng has a substantial expanse. The land use category includes a zone designated for apartment and automobile parking. The area has sufficient illumination during the night and is equipped with CCTV. There are six alternative methods to enter and exit the location. There is no police red box checkpoint at R2.

R3: Room for rent (unnamed) is situated in the village area adjacent to the main road, approximately 3 meters away. This road is commonly utilized by individuals for transportation purposes. No fence around the room for rent. Villages and vacant lands are the types of land use in the vicinity of the incident. There is plenty of illumination during the night and none of the area is equipped with CCTV. There is no police red box checkpoint at R3.

R4: The Panee room for rent in Khlong Tamru is situated adjacent to the major road and near Sukhumvit Rd, a roadway frequently utilized by individuals for transit purposes. The room rental does not include a fence. There are a total of 10 rooms available for rental. The area surrounding the incident encompasses various land uses, such as settlements, vacant land, and official departments. There is plenty of illumination during the night and none of the area is equipped with CCTV. There is a lack of police red box checkpoints in R4.

5.2 Conclusion

The risk areas classified as stolen motorcycles under the jurisdiction of Mueang Chonburi Police Station were evaluated using Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE). The findings indicate that Nong Mai Daeng exhibits the highest risk level, followed by Khlong Tamru, which serves as adjacent to Nong Mai Daeng.

The analysis utilizes crime statistics spanning the years 2019 to 2023. The integration of hot spots derived from Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE) has the potential to enhance each other's performance and yield improved outcomes. The Getis-Ord Gi* has demonstrated its efficacy in identifying crime clusters and risk within the research area, similar to the other two GIS-based approaches. The Inverse Distance Weighted interpolation approach was employed to enhance the visualization of the results obtained from the Getis-Ord Gi* hot spot study. The Kernel Density Estimation (KDE) technique yields data that offers a seamless representation of crime severity and enhances the display of crime-affected areas, resulting in a slightly higher number of places identified as crime hot spots. The hot spot zones exhibited a high degree of similarity across all the methodologies employed.

A minimum of two techniques produced similar results. In 2021, KDE recognized Ban Khot and Makham Yong as the sole locations with a significant risk area. In contrast, the outcomes of the remaining two methodologies failed to predict Ban Khot and Makham Yong as potential areas of concern within a timeframe of five years.

The areas of Nong Mai Daeng and Khlong Tamru have been classified as crime hot spots characterized by a significantly high-risk level. The police services in these locations necessitated heightened attention. Nevertheless, it can be inferred that none of the procedures exhibit a high level of accuracy and yield 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 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, 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. Subsequently, the research questions will be elucidated as follows:

1. Do low-risk areas have a higher number of red box checkpoints compared to very high-risk areas?

The results of all three techniques are similar, suggesting that Nong Mai Daeng continually presents itself as a risk location for motorcycles theft, but with different levels of peril. Unlike other areas with lower crime rates, such as Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong, the correlation between the presence of 408 police red box checkpoints and the risk areas of crime suggests that the number of police red box checkpoints in the risk area of Nong Mai Daeng is relatively lower. In the vicinity of Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong, the predominant land use types are commercial facilities, namely gold shops, which require periodic inspections conducted by patrol police. A total of more than 50 gold shops are jointly encompassed by Ban Suan, Bang Pla Soi, Ban Khot, and Makham Yong. Numerous gold enterprises are furnished with police red box checkpoints to guarantee security. Hence, these areas exhibit a higher concentration of police red box checkpoints in comparison to the Nong Mai Daeng zone.

2. What are the similar results between the risk area prediction findings obtained via Getis-Ord Gi*, IDW, and Kernel Density Estimation (KDE)?

The three methodologies produced similar predictions for the period spanning from 2019 to 2023, designating Nong Mai Daeng as a site of risk levels, namely medium, high, and very high. Kernel Density Estimation (KDE) has determined that Nong Mai Daeng is the location with the greatest risk during the COVID-19 timeframe. KDE is the only methodology that can predict hazardous areas in 2020, given the scarcity of 22 recorded criminal cases this year. Except for a few sites where there are minor differences in the results.

3. Did there be any changes in hot spots and high-risk areas for victimization before, during, and after the COVID-19 pandemic?

Nong Mai Daeng and Khlong Tamru have consistently maintained their status as the most risk areas before, during, and after the enforcement of COVID-19 restrictions. However, a significant change has been observed in the number of motorcycles that have been subject to theft. The frequency of stolen incidents has consistently increased throughout the years, with a significant jump noted in 2023.

There were 146 documented cases, suggesting the existence of hazardous areas in several locations, such as Ban Khot and Makham Yong.

This paper presents the proposed method for addressing the issue of stolen motorcycles within the jurisdiction of Mueang Chonburi Police Station, utilizing the Crime Prevention through Environment Design (CPTED) approach.

1. 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 "Zero Tolerance" policy should be implemented to address the issue of stolen motorcycles inside the high-risk zones R1, R2, R3, and R4. Risk area R2: The Ninja market needs an increased presence of police patrols in response to the recurrent occurrences of 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 principles possesses the capacity to amplify the 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 extend assistance to e-bike users as a viable substitute for motorcycles within the country. Use smart chips with e-bikes to prevent stolen of e-bikes. The cost of e-bikes is comparatively cheaper than that of motorbikes. As a result, the criminals

will suffer financial damages due to their illegal actions, while the associated punishments will stay the same, as they commit theft of property. In addition, the Wuhan Municipal Bureau of Public Security recorded a total of 1594 stolen electric bicycles between January 1, 2013, and August 31, 2013 [22]. In 2018, the municipality of Wuhan, located in Central China, implemented its version of the Internet of Things (IoT) to mitigate the occurrence of theft incidents involving electric bicycles owned by its residents. Wuhan effectively deployed its Internet of Things (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[52]. To safeguard the safety of riders and promote their trust in using e-bikes, the Thai government must establish a separate bike lane exclusively for e-bikes, apart from the existing car lanes.

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