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Research article

Exploring Spatial Relationship in Criminal Behavior: A Spatial Analysis of Offenders' Homes and Theft Locations in Kuching, Sarawak, Malaysia

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Abstract

This study aims to identify the proximity of offenders' homes to the theft location in Kuching, Sarawak. The attribute data includes the total number of theft offenders in Kuching in 2018, categorized as solo and co-offenders. It also details the modus operandi used in these thefts, as well as the offenders' employment and educational backgrounds. At the same time, spatial data consists of Kuching and Samarahan land use types, Kuching police station sector boundaries, the home addresses of offenders, and the locations where thefts occurred. This study applied standard deviation ellipses, Euclidean distance analysis, and kernel density estimation. The findings indicate that young people and individuals in their late twenties (15-29 year olds) are at a higher risk of engaging in theft activities. Their target areas are often close to their homes, particularly in urban areas lacking CCTV and security guards. Offenders in urban areas, who are unemployed at the age of 15-29 years old and have low education (SPM level), tend to be thieves. Both solo offenders and co-offenders tend to commit theft near their home. The total number of solo offenders of theft is 78.5%, and co-offenders are 21.4%. The analysis reveals a high level of spatial clustering among offenders, with their homes concentrated in the urban center of Kuching, where crime is most prevalent. The findings imply that offenders' residences are localized in specific urban areas rather than being evenly distributed across the districts of Kuching, Sarawak. The offenders typically travel short distances when engaging in property crime, especially theft. The study suggests that land use planning should consider the concentration of offenders in urban areas. The study also highlights the importance of targeted patrols in high-crime urban areas, especially those lacking CCTV and security guards.

Keywords: spatial analysis of crime; criminal behaviour; Offenders' Home; Theft Locations

1. Introduction

Property crime has emerged as a significant challenge in major cities of developing countries, including those in various regions around the world (Andrew *et al.*, 2013). Studies on property crime have explored this issue in various aspects. Property crimes, such as looting, aggravated theft, check misappropriation, vehicle part theft, robbery, bribery, corruption, and money laundering, have become a prevalent social issue in Ethiopia (Jubit *et al.*, 2015). Property crimes account for more than half of the reported crimes in Portugal, highlighting the significant prevalence of offenses related to property in the country. The study identified key factors influencing crime rates, such as the young resident population, education indicators, economic conditions, and demographic characteristics (Wang *et al.*, 2023). Property crimes often occur in specific areas due to various circumstantial factors. By analyzing police reports and demographic data related to offenders, as well as the location of crimes and offenders' residences, it is possible to identify the factors that influence crime in these particular areas. This data can provide valuable insights into the patterns of property crime, the characteristics of offenders, and the environmental factors that contribute to criminal activities in specific locations. According to reports, property crime accounted for a significant 88.8% of reported crimes, while violent crime constituted 11.2% during the period from 2004 to 2016 (Jubit & Masron, 2022).

Offenders tend to travel shorter distances to commit crimes in robbery and aggravated assault hot spots (Tavares & Costa, 2021). Besides that, Ruiter (2017) identified that research usually focused on offenders' residential areas to measure their awareness spaces, assuming that offenders primarily spend their time near their homes. This approach has been commonly used in studies to understand offenders' spatial behaviors and decision-making. Offenders are significantly more likely to commit offenses within their activity spaces compared to other locations, with the likelihood of offending increasing as the frequency of visits to these spaces rises (Menting *et al.*, 2020). This

suggests a strong correlation between offenders' routine activities and the occurrence of criminal behavior. In addition, Hodkinsoi and Tilley (2007) found that environmental criminology examines the spatial patterns of crime by focusing on the location of the offender and victim at a specific time and place. It explains crime patterns based on the everyday activities of the offender. Offenders usually commit crimes close to where they usually go, within their familiar surroundings.

The other researcher, Lent *et al.* (2022), discuss that the decision-making process leading to the commission of a crime is influenced not only by individual characteristics but also by the broader environmental context in which the crimes take place. Burglars tend to target neighborhoods that are close to their residences, near the city center, affluent, easily accessible, and characterized by a lack of social order. Researchers have looked at how these factors affect burglars who work alone versus those who work in groups. The findings show that both solo burglars and groups of burglars find areas near their homes that are easy to access and appealing (Bernasco & Dijke, 2020).

The factors that influence crime, as highlighted in the previous study, include the distances at which offenders operate, their familiarity with the surrounding environment, the presence of opportunities for crime, and the age of offenders (Wang *et al.*, 2015). Offenders often commit crimes within short distances from their usual locations, taking advantage of their awareness space (Tavares & Costa, 2021). Familiarity with the environment where crimes occur plays a significant role in the selection of crime locations. The presence of opportunities, such as vulnerable targets or a lack of security measures, can increase the likelihood of criminal activities. Additionally, the age of offenders can impact the types and frequency of crimes committed, as different age groups may have varying motivations and risk-taking behaviors (Kuching Police Station Report, 2018).

Previous studies from the literature reviews have focused on identifying crime hot spots, areas with significantly higher crime rates, through spatial mapping to facilitate targeted interventions (Hodgkinsoi & Tilley, 2007). Additionally, research has explored the spatial distribution of property crimes like burglary and theft to recognize trends and clusters for effective resource allocation. The impact of external factors, such as the COVID-19 pandemic, on property crime rates has also been a subject of investigation, utilizing GIS to assess changes in crime patterns during crises (Ahmad *et al.*, 2024). Previous studies have mainly neglected the connection between where offenders reside and where they commit crimes. Previous studies, such as Bernasco (2012) and Michaund and Proulx (2023), have limitations due to the oversimplification of police data and the journey to crime measurement. It suggests that these methods fail to capture the true complexity of offender travel patterns, which often involve multiple destinations and do not follow a simple home-to-crime-to-home route.

Furthermore, analyses have examined the spatial relationships between offenders and victims, including the distances between their residences, to gain insights into criminal behavior and victim-offender interaction. In this study, we investigate the proximity of offenders' residences to theft locations in Kuching, Sarawak. At the same time, also analyze the modus operandi and ages of the offenders involved in these criminal activities. By focusing on these specific aspects, the research seeks to understand the spatial dynamics of theft incidents in the study area and explore the methods and characteristics of the offenders perpetrating these crimes.

This study will provide valuable insights into the geographical relationships between offenders' homes and theft locations, shed light on the tactics used by offenders in committing theft, and offer demographic information regarding the ages of individuals involved in these criminal acts. By examining these factors, the study aims to contribute to a deeper understanding of theft patterns and inform targeted interventions and strategies to address and prevent theft incidents effectively in the affected areas.

2. Literature Review

Bernasco (2012) explores how criminals and their targets converge in time and space. Crime depends on the intersection of offenders and suitable targets, and offenders often commit crimes in familiar areas or along their regular routes. The study suggests that smartphones can provide rich data on offender movements, location history, and communication patterns, leading to a deeper understanding of the crime journey. Other researchers, such as Michaund and Proulx (2023), aim to quantify the biases inherent in the journey to crime measurement, which is often used to estimate the distance offenders travel during a crime. The study found that police data often contained inaccurate offender home addresses, potentially leading to miscalculations of journey distances. Offenders frequently visit multiple locations before, during, and after committing a crime, making it difficult to calculate the total distance traveled accurately.

The previous study, Hodgkinsoi and Tillet (2007), utilized the Global Moran's I tool to assess the overall spatial pattern and trends of property crime in Kuching, Sarawak. The analysis revealed that the spatial distribution of property crime in Kuching during 2015-2017 exhibited a random pattern, as indicated by a p-value greater than 1.0 and a Moran's Index approaching zero. However, stolen cases exhibited a positive spatial autocorrelation, with clustered incidents identified in 2015 and 2017 at a 90% confidence level. Another study conducted by Jubit *et al*. (2021) utilized Kernel Density Estimation (KDE) to pinpoint hot spots of motorcycle theft. Their research revealed that the hot spots of motorcycle theft vary both annually and over different times, indicating a dynamic pattern in the distribution of these criminal activities.

Apart from that, Ahmad *et al*. (2024) investigated the impact of COVID-19 and the Movement Control Order (MCO) on the trend of property crimes, spanning from 2020 to 2022. The government imposed lockdown measures that significantly altered daily activities in Malaysia, including Kuching, Sarawak. The research methodology incorporates descriptive and spatial analyses, specifically utilizing the Hot Spot Getis Gi* technique with the assistance of ArcGIS software to explore the relationship between crime and geography.

The study reveals a decline in property crime cases from 1,144 in 2020 to 813 in 2021, further decreasing to 683 cases in 2022. The GiZScore ranged from a low of 2.066694 to a high of 13.365677 in 2021. Despite the Movement Control Order (MCO) in place from March 2020 to November 1, 2021, property crimes persisted in Kuching's urban center. The study indicates a significant reduction in property crime trends during the COVID-19 pandemic period (2020-2021) due to the MCO and subsequent lockdown measures that continued into the endemic phase of 2022. These findings underscore the effectiveness of the Royal Malaysia Police, particularly in the context of Kuching, Sarawak, in responding to and mitigating property crimes during challenging circumstances.

Some researchers, such as Bench *et al.* (2022), found a significant reduction in protective order violations to nearly zero when the victim and offender resided 25 miles or more apart. Notably, this outcome remained consistent across various forms of contact, including physical, telephone, and cyber interactions. The study concludes by discussing the policy implications of these results and provides recommendations for future research in this area. By using mean center and SDE, it was found that despite coastal Guyana initially being the focal point for the majority of crimes, there has been a notable shift in the center of gravity of these criminal activities over the years (Cummings *et al.*, 2019). This shift has extended into landscapes influenced by indigenous peoples, indicating a changing pattern in the distribution and prevalence of crimes in the region.

Interestingly, Fondevilla *et al.* (2021) compares the effectiveness of a gradual decrease in crime with distance from police stations versus a defined buffer zone around them. The goal is to identify consistent crime patterns relative to police station locations, excluding other factors. Using a new daily dataset from 2016 to 2019 on property crimes (robbery, theft, car theft) and personal crimes (homicide) in Buenos Aires, the study reveals a nonrandom concentration of crimes. The research indicates that crime rates rise exponentially with distance from the nearest police station, peaking at 500–600 meters before declining. These findings suggest that police stations have a deterrent effect on crime. Other researchers, such as Aslam and Naseer (2020), utilized mean center and standard deviation ellipse analysis to investigate the directional distribution of various classes of earthquakes, ultimately concluding on the seismic activity within the Balochistan region. The mean center identifies the geographic midpoint (epicenter of concentration) for a specified range of earthquakes. However, Ham *et al.*, (2022) using discrete spatial choice models, the study examines the proximity to precrime activity locations, such as offenders' homes, family members' homes, schools, prior criminal activities, and other police interactions, in relation to various types of crimes in New Zealand, including residential burglaries, non residential burglaries, commercial robberies, personal robberies, and extra familial sex offenses.

The findings indicate that offenders tend to commit crimes closer to their activity locations, particularly those visited more frequently or those likely to provide valuable information about crime opportunities. The study reveals that the spatial relationships between different activity locations and crime types align with an extended crime pattern theory, emphasizing the importance of distinguishing between activity locations and crime types in understanding criminal spatial behavior. In addition, Aniyar and Jacome (2022) examined the impact of Euclidean distance between police stations and crime locations on the decrease in crime rates. The research found that when police stations were closer to crime areas and specific strategies were in place, there was a noticeable drop in crime rates. The study of crime among offenders, including age, solo and co-offending, offenders' home, and theft location, has been largely unexplored due to limited access to the data.

3. Method

The research was carried out in Kuching, due to reports indicating that this district has the highest incidence of property crime compared to other district in Sarawak (Kuching Police Station Report, 2018). Kuching experienced a significant disparity in crime types between 2015 and 2017, with property crime dominating the statistics. During this period, 4,123 cases (81.3%) were classified as property crime, while violent crime accounted for approximately 18.6% of the total reported incidents (Jubit *et al.*, 2020). Kuching and Samarahan land use types were obtained from the Land and Survey Department. The data was obtained from the Crime Investigation Division of Kuching Police Headquarters. The offender's home and theft location data were collected directly from the Police Reporting System. The attribute data includes theft type, police station, date, and address of theft occurrences, offender age, home address, occupation, education level, marital status, gender, race, and whether the offender acted alone or with co-offenders. All data were sorted in Excel before being added to ArcGIS 10.7. The Kuching District Police Headquarters oversees nine police stations, including Padungan, Bintawa, Sekama, Tabuan Jaya, Sungai Maong, Gita, Santubong, Central, Satok, and 57 police station sectors as shown in Figure 1.

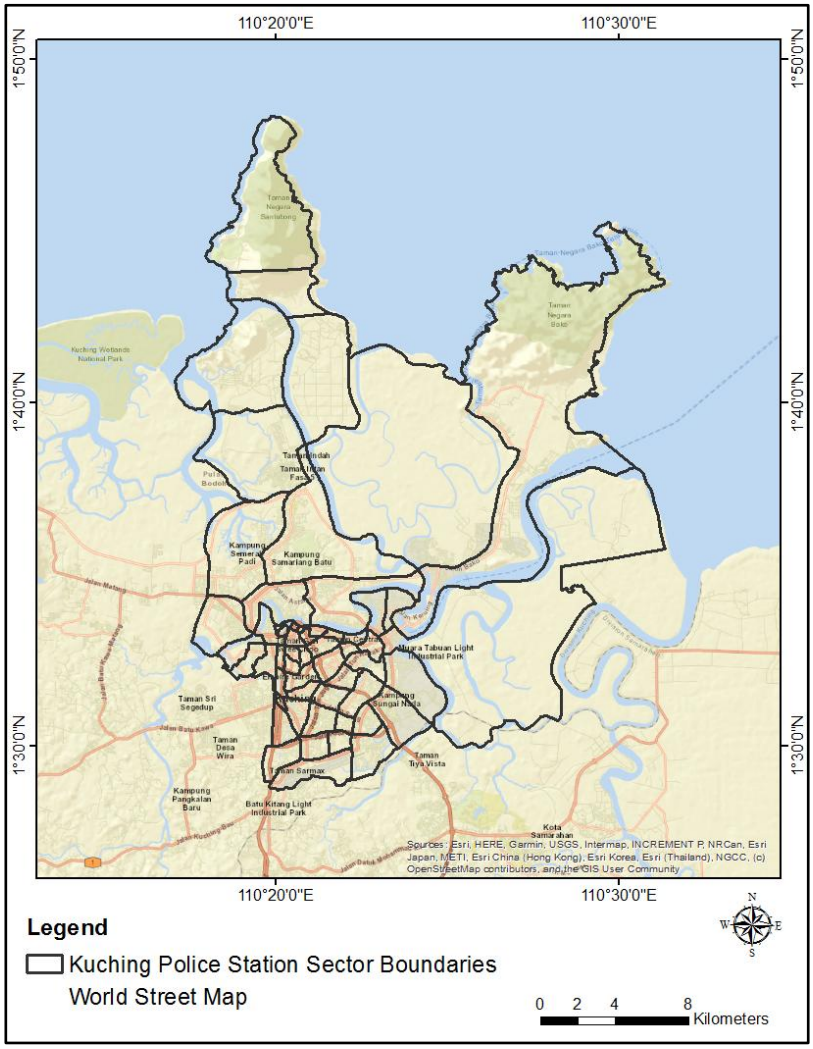

Figure 1. Study area.

The standard deviation ellipse is an ellipse showing the typical spread of points around the average center point. It also forecasts the likelihood of future occurrences within specific crime series; aids in pinpointing the clustering of incidents over an extended period, highlighting persistent trends or issues. However, the mean center helps in pinpointing the average center of a set of points (such as incidents or offenders' addresses). Standard deviation is a traditional statistical measure used to show how spread out or scattered individual features are from the average or central value in a dataset. Equations 1, 2, and 3 help illustrate the extent to which data points deviate from the mean or center of the data distribution (Wang *et al.*, 2015).

$$tan\theta = \left(\frac{A+B}{C}\right) \quad (1)$$

$$A = \left(\sum_{t=1}^{n} w_1^2 \tilde{x}_1^2 - \sum_{t=1}^{n} w_1^2 \tilde{y}_1^2 - \right) \quad (2)$$

$$\begin{Bmatrix} \tilde{x}_1 & = & x_1 - \bar{X} \\ \bar{\tilde{y}}_1 & = & y_1 - \bar{Y} \end{Bmatrix} \quad (3)$$

To analyze the spatial distribution of offenders' homes and theft locations, the distance standard deviation ellipse method is employed in this study. In this context, θ denotes the orientation of the error ellipse, which signifies the angle measured clockwise from the north direction to determine the major axis of the error ellipse. $\tilde{xi}$ and $\tilde{yi}$ represent the deviations from the weighted average center to the steel structure building i. wi indicates the weight, reflecting the proportion of the steel structure building area in this investigation. The standard deviations in the *X* and *Y* directions are calculated using Equation 4 (Chen *et al.*, 2023).

$$\begin{Bmatrix} \sigma_x & = & \sqrt{\frac{\sum_{i=1}^{n}(w_i \tilde{X}_i cos\theta - w_i \tilde{Y}_i cos\theta)^2}{\sum_{i=1}^{n} w_i^2}} \\ \sigma_y & & \sqrt{\frac{\sum_{i=1}^{n}(w_i \tilde{X}_i cos\theta - w_i \tilde{Y}_i cos\theta)^2}{\sum_{i=1}^{n} w_i^2}} \end{Bmatrix} \quad (4)$$

Within the standard deviation ellipse, the long semi-axis indicates the direction with a greater dispersion, whereas the short semi-axis signifies the direction with a higher clustering tendency. A significant contrast between the two axes emphasizes the directional pattern of the data. According to Chen *et al.* (2023), standard deviation ellipse analysis is a commonly used method to assess the distribution characteristics of spatial points. The key outcomes of this analysis encompass the mean center, long axis, short axis, and ellipse orientation. The mean center identifies the central point of gravity of the offender's home and theft location distribution. The long axis indicates the orientation of the offender's home and theft location distribution, while the short semi-axis denotes the extent of the offender's home and theft location distribution. When the long axis and the short axis are in close proximity, the dispersion of offender's home and theft locations distribution are higher, and spatial clustering is less pronounced. Conversely, a greater separation between the long and short axes signifies a more distinct spatial agglomeration of offenders' homes and theft locations. The mean center (Equation 5) has been used to analyze the offender's home and theft location center growth (Litasari *et al.*, 2020). This formula investigates the spatial weighted mean center.

$$\bar{X} = \frac{\sum_{i=1}^{n} Z_i X_i}{\sum_{i=1}^{n} Z_i}, \bar{Y} = \frac{\sum_{i=1}^{n} Z_i X_i}{\sum_{i=1}^{n} Z_i} \quad (5)$$

The values Xi and Yi represent the geographical coordinates of polygon centroid i. Each polygon is weighted based on its area, denoted by zi. $\bar{X}$ and $\bar{Y}$ denote the spatial mean center. This formula was utilized during the three-point time of the built-up to determine the growth direction.

3.1. Euclidean Distance

To evaluate the spatial relationship between each offender's home and theft location, this study applied Euclidean distance. The function of Euclidean distance provides the straight line distance between the theft location point and the offender's home (Andrew *et al.*, 2013). It also provides a more accurate description of the distance between the theft location and the offenders' homes.

3.2. Kernel Density Estimation

By utilizing kernel density estimation, statisticians can create continuous and smooth representations of the probability density function based on the observed data points (Danese *et al.*, 2008). Kernel density also helps to identify the patterns of the points, revealing whether the distribution of points exhibits clustering, randomness, or other spatial patterns. In addition, KDE could help to identify spatial relationships among variables. The initiation of Kernel Density Estimation (KDE) involves segmenting a continuous map surface into a grid comprising predefined cell sizes (King *et al.*, 2016). KDE conducts density calculations based on userspecified search bandwidth and kernel functions. This process involves estimating the probability density function by leveraging the inherent characteristics of the data sample. The function of Kernel Density is varied as it can calculate the weights and create a spatial weight (Wu & Li, 2022). Besides that, Chainey (2013) found that to produce KDE output, two main parameters should be considered, such as the cell size and bandwidth size. Thus, this study uses two parameters in identifying hot spots of offenders' homes and theft locations.

4. Result and Discussion

According to the Kuching Police Station Report (2018), the total losses from theft amounted to RM 1,105,826.40. The police also reported the total number of offenders, categorized by age groups as depicted in Figure 2.

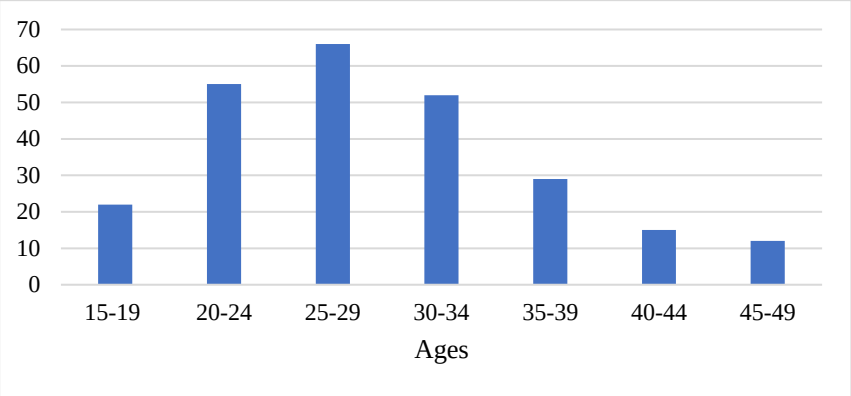

Figure 2. The Total Number of Theft Offenders in 2018.

The classification of thieves' age is based on the demographic age classification of the population issued by the Department of Statistics. The highest number of offenders were aged 25-29 years, totaling 27% individuals, followed by offenders aged 20-24 years with 22% individuals. The third highest group consisted of offenders aged 30-34 years. The statistics indicate that the number of theft offenders in Kuching increases from the age group of 15-29 years and then decreases for individuals aged 35 years and above. This trend suggests that adolescents and young adults are more likely to be involved in theft activities. This suggests that young adults and individuals in their late twenties are more inclined to engage in theft. The peak age group for theft offenders, being 25-29 years old, indicates a specific demographic that law enforcement agencies can target for prevention and intervention strategies. The increase in the number of offenders from the age group of 15-19 years to 25-29 years highlights the vulnerability of adolescents and young adults to involvement in theft activities. This underscores the importance of early intervention and support programs for at-risk youth. The decrease in the number of offenders in the age group of 35 years and above suggests a shift in criminal behavior towards younger age groups. Understanding this trend can help in tailoring prevention efforts to address the specific needs of different age cohorts. By analyzing these insights, authorities can develop proactive measures to address theft issues effectively, focusing on the specific age groups most at risk of engaging in theft activities.

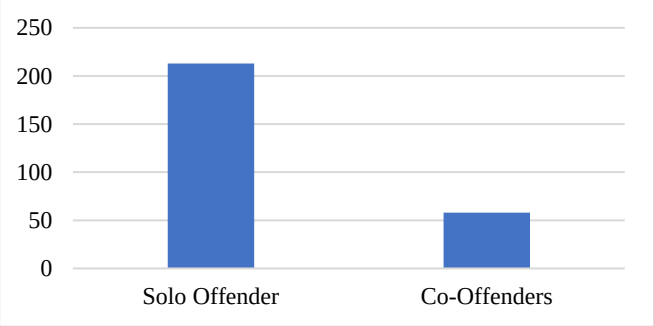

Figure 3. The Total Number of Solo and Co-Offenders in 2018.

The difference in the total number of solo offenders of theft, which is 78.5%, and co-offenders, which is 21.4%, can be attributed to the nature of the crimes committed and the dynamics of criminal behavior. Solo offenders are individuals who commit crimes independently without the involvement of others. They may choose to act alone due to various reasons, such as the desire for autonomy, lack of trust in others, or the nature of the crime being easier to execute alone. In the case of theft, solo offenders may prefer to work alone to minimize the risk of being caught or to keep the stolen goods for themselves without having to share with others. On the other hand, co-offenders are individuals who commit crimes in collaboration with others. This could be due to factors such as shared criminal intent, division of labor to carry out the crime more efficiently, or peer pressure within a criminal group. In the context of theft, co-offenders may work together to target larger or more challenging thefts that require coordination and teamwork. The disparity in numbers between solo offenders and co-offenders in theft cases could indicate that thefts

committed by solo offenders are more common or easier to execute compared to those involving co-offenders. It may also reflect the prevalence of individual criminal behavior in theft-related offenses.

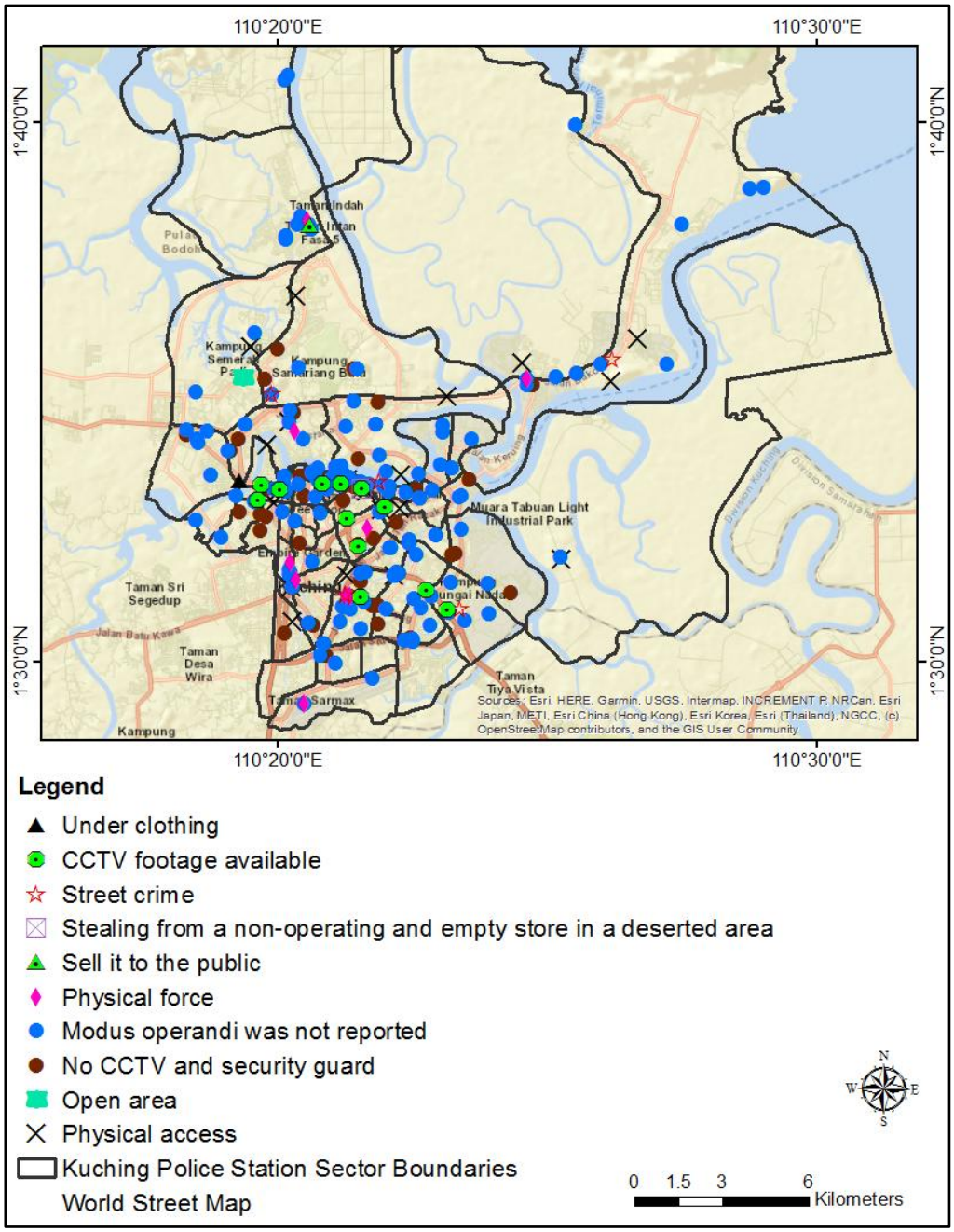

Figure 4. Spatial Distributions of Modus Operandi Used in Theft.

In the analysis of theft incidents based on different modus operandi, it is evident that a significant number of cases, specifically 61.6% incidents, lack reported details on the methods used (Figure 4). This lack of documentation poses challenges in investigating and preventing such crimes effectively. Additionally, the data reveals that 19.2% incidents occurred in locations without CCTV cameras and security guards, indicating a vulnerability in security measures that perpetrators exploit. On the contrary, in 5.6% incidents where CCTV footage was available, it played a crucial role in identifying suspects and investigating the thefts. The availability of CCTV footage proved instrumental in successfully resolving most cases, leading to the detection and apprehension of perpetrators with the assistance of CCTV technology. Furthermore, incidents involving unlocked car windows or doors (3.6% incidents) underscore the importance of securing vehicles to deter opportunistic theft. Instances of forcefully breaking windows, doors, or CCTV cameras (3.2% incidents) suggest a more aggressive approach by perpetrators, potentially leading to increased property damage. The presence of unfenced areas (2% incidents) and cases where perpetrators climbed windows or fences (1.6% incidents) highlights the need for stronger physical barriers and

security measures. The deliberate act of cutting fences, locks, or wires (1.6% incidents) showcases the determination of criminals to bypass security measures. Moreover, the involvement of motorcycles (0.8% incidents) and the discreet use of bags (0.8% incidents) in theft activities demonstrate varying methods employed by perpetrators. This comprehensive analysis provides valuable insights into the modus operandi prevalent in theft incidents, offering a basis for enhancing security measures and devising strategies to combat such criminal activities effectively.

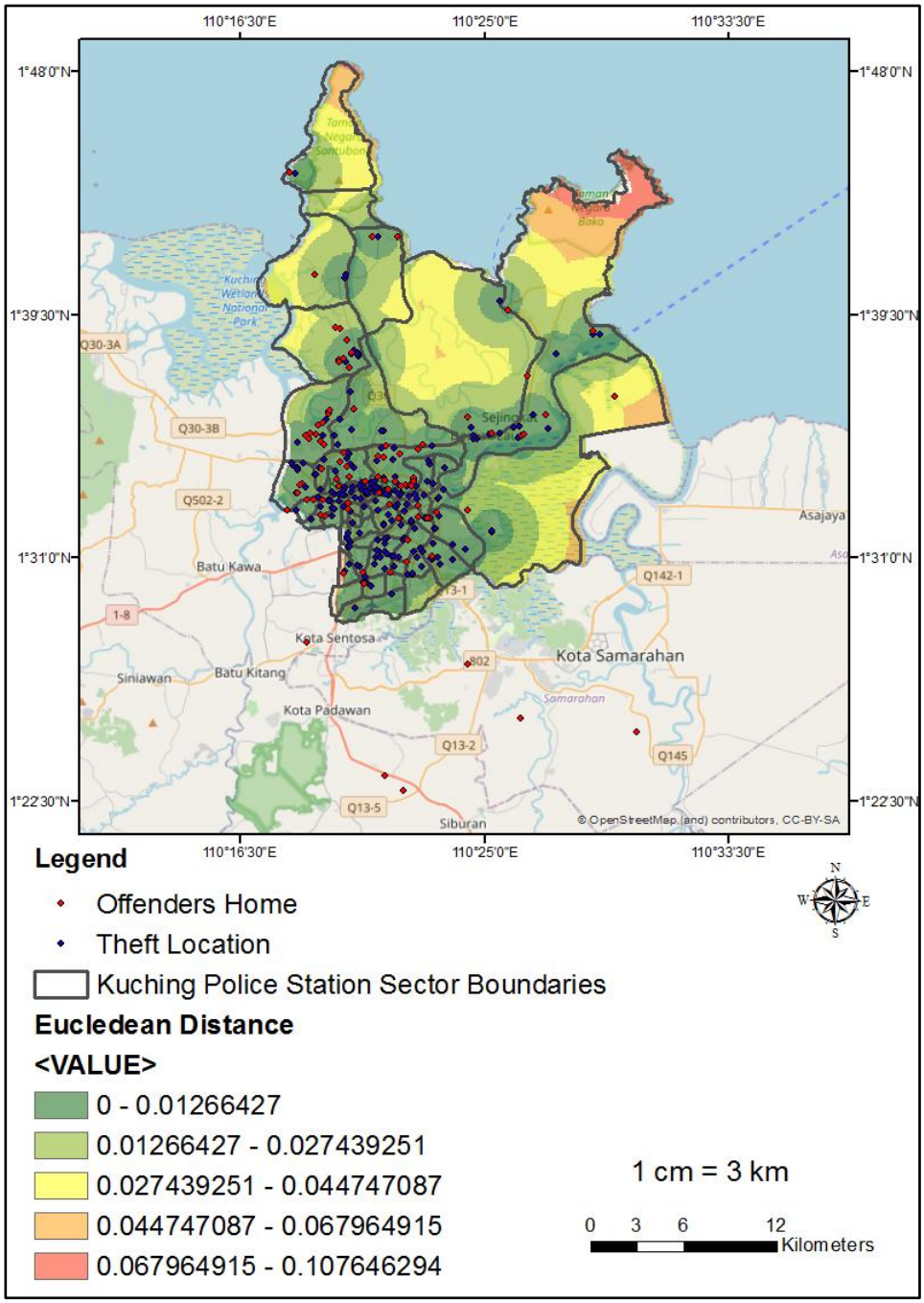

Figure 5. Euclidean Distance Analysis Between the Offender's Home and the Theft Location

The distance between the offender's home and the location of theft was measured using Euclidean distance (Figure 5). Each address of the offender's home and the theft location was geocoded to obtain their x and y coordinates. Each offender's home and the theft location were pinpointed on a map using their addresses to determine their exact coordinates. The distances were classified into four categories: 0-0.01266427 meters, 0.01266427-0.027439251 meters, 0.027439251-0.044747087 meters, 0.044747087-0.107646294 meters. The color variations visualize the distances between different theft locations and between each offender's home and the theft locations. The closest locations between the offender's home and the theft location were found in police station sectors like Padungan, Gita, Sekama, Sungai Maong, Tabuan Jaya, Satok, and Sentral. Most theft locations and offenders' homes were very close together (within 0-0.01266427 meters).

The proximity strongly suggests that the offenders likely committed the thefts in locations near their homes. This could be due to convenience, familiarity with the area, reduced risk of detection, or a combination of factors. However, the farthest distances between the offender's home and the theft location were observed in the Santubong police station sector. This suggests that most offenders and theft locations are concentrated in urban central areas, but are not necessarily close to each other when far from the urban center of Kuching. Offenders tend to choose crime sites that are near their homes, where there is no CCTV. However, some offenders' homes were located far from the theft location. A significant security vulnerability is evident in the data, with 19.2% of incidents occurring at locations lacking CCTV cameras and security guard presence. This indicates that most offenders and theft locations tend to be clustered in urban central areas. However, when they are far from the urban center of Kuching, the relationship between the offenders' homes and theft locations becomes less significant. The findings suggest that offenders are more likely to commit crimes in locations that are close to their homes, as evidenced by the patterns observed in the distances between offenders' homes and theft locations in the study.

4.1. Crime Distributions Based on Land Uses

The strength of the direction of the offender's home in different land uses is shown in Figure 6. The standard deviational ellipse analysis shows that the data points are centered at coordinates (73509.113488, 172855.387277) with standard deviations of 7562.761319 along the X-axis and 8416.021522 along the Y-axis.

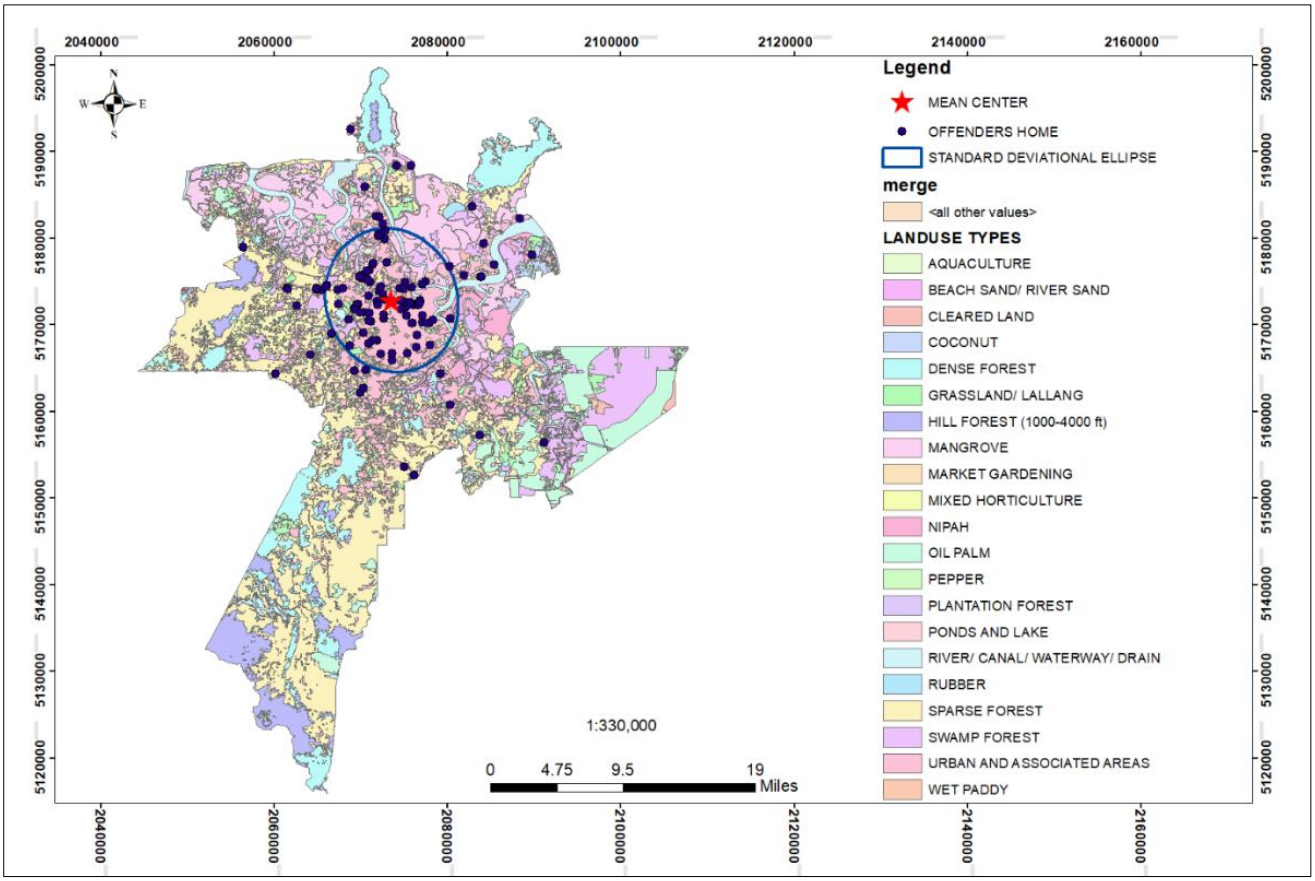

Figure 6. The Mean Center and Standard Deviational Ellipse Analysis Results of Offenders' Home Locations

The ellipse is rotated at an angle of 157.713631 degrees, providing insights into the spatial distribution and orientation of the offender's home. Looking at the shape of the ellipse, the offender's home location has a small ellipse. This result suggests that the offender's home has a more clustered distribution. The small ellipse around the offenders' homes signifies a high level of spatial clustering, indicating that these individuals tend to reside near each other. The location of offenders' homes is concentrated in urban centers, indicating that many offenders reside in areas with the highest crime concentration.

This finding implies that the offenders' residences are concentrated in specific areas rather than being evenly distributed across the districts of Kuching. The clustered distribution of offenders' homes in urban areas underscores the significance of urban environments in Kuching in shaping criminal behavior. The concentration of offenders' homes in the urban center, where crime is most

prevalent, raises questions about the relationship between residential location and criminal activity. It may reflect underlying socio-economic disparities, lack of opportunities, or other environmental factors that influence criminal behavior and contribute to the spatial distribution of offenders in Kuching.

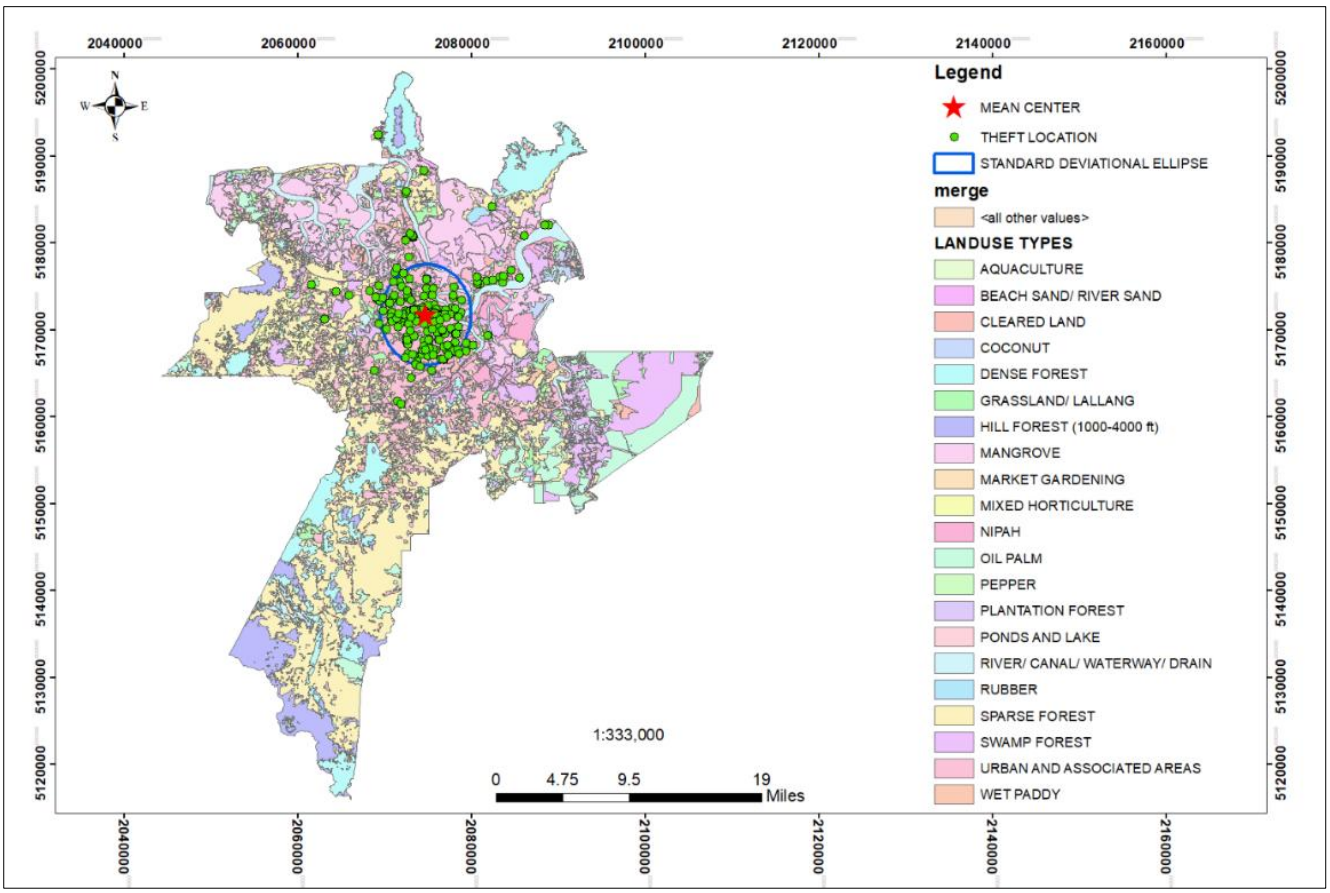

Figure 7. The Mean Center and Standard Deviation Ellipse Analysis Results of Theft Location.

The ellipse of the theft location is smaller than the spatial distribution of the offender's home, as shown in Figure 7. This indicates that the theft locations are more concentrated and have high clustering in urban areas rather than being spread out from the urban center. The values signify essential properties of the ellipse: Center X (110.356478) and Center Y (1.553394) represent the coordinates of the ellipse's center along the X and Y axes, respectively. Furthermore, XStdDist (0.046648) and YStdDist (0.052623) denote the standard deviations of the ellipse's dimensions along the X and Y axes, illustrating its width and height.

The rotation value (4.239062) indicates the angle of rotation of the ellipse, influencing its orientation relative to the X-axis. According to the result circle of the ellipse, it indicates that theft locations are clustering in certain areas in the urban area. The ellipse is relatively small size. The mean center of crime locations, calculated based on the provided XCoord and YCoord values (110.356478, 1.553394), represents the average geographical center point of the reported crime incidents. In this case, the mean center coordinates (110.356478, 1.553394) indicate the central location where the reported theft are clustered or distributed. This mean center serves as a statistical measure to summarize the spatial distribution of theft incidents, providing valuable insights into the overall pattern and concentration of theft activities in the area.

When looking at the map, the points of theft locations tend to be concentrated in urban and associated areas. Socioeconomic factors are a reason why theft locations are concentrated in urban areas. This is because most offenders have a background of having a spm level and are between the ages of 15 and 29 years old with no job. Many offenders choose to commit crimes in these urban and associated areas, which can be referred to as targeted areas with the highest potential. The offenders have a high opportunity in these areas, indicating that the areas are not safe for property. According to the modus operandi reported to the police stations, the absence of guards and CCTV was reported highest at theft locations, providing an opportunity for criminals to take action in these areas.

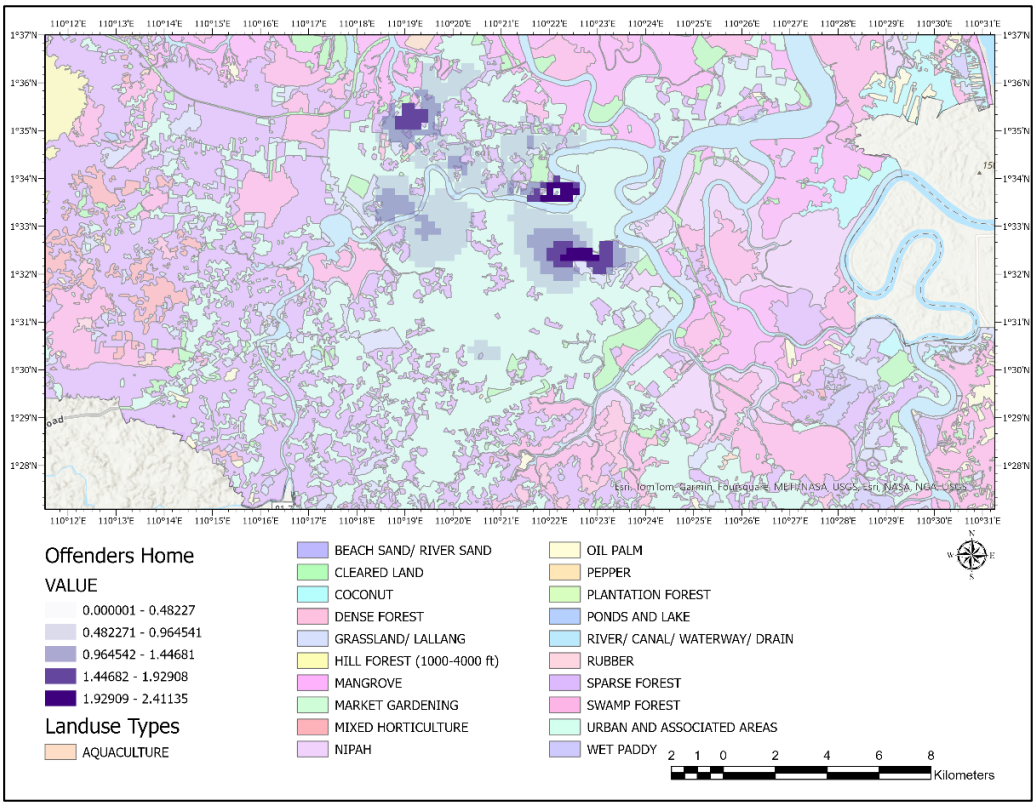

Figure 8. Kernel Density of Offender Home.

Figure 8 shows the Kernel Density analysis of offenders' homes in Kuching, Sarawak. ArcMap automatic extraction, Output cell size: 2.28 meters, search radius or bandwidth 0.01. The analysis aims to identify the spatial patterns of offenders' homes and where the points are concentrated. According to the results, the points of offenders' homes were detected in specific areas of police station sectors, including sectors 1 and 4 of Gita police station, sectors 3 and 4 of Padungan police station. Hot spots were also detected in other areas, such as sector 3 of Sekama police station, sector 1 in Bintawa police station, sector 2 of Tabuan Jaya police station, and sector 5 in Santubong police station. In total, there were 8 hot spot areas. Most of them were detected in urban and associated areas, indicating that all offenders live in urban areas. This information could help the police understand the concentrated areas of offenders' homes and potentially implement programs to increase awareness of property crime within the community residing in these areas. People living in urban areas may be more likely to be involved in criminal activities, particularly property crimes, and some of them also have a high chance of becoming victims of property crime. Many of the offenders are aged between 25 and 29 years old and have been arrested by the police. The report revealed that these offenders are also unemployed, which has led them to get involved in theft. High levels of poverty and unemployment in certain neighborhoods can create environments where individuals may turn to criminal activities as a means of survival. Economic deprivation can increase the likelihood of criminal behavior among residents in these areas. All these can be the factors of offenders' home being concentrated in specific areas of police station sectors.

In urban areas, various activities such as commercial ventures, residential living, and urban amenities attract a large number of people for shopping, work, and residence. The bustling nature of urban areas results in crowded spaces on a daily basis. The higher the concentration of people in these areas, the greater the likelihood of theft occurrences, especially in locations where there is an absence of CCTV surveillance, security guards, and witnesses to act as guardians. The presence of numerous commercial establishments and residential properties in urban areas creates opportunities for theft, as the high volume of foot traffic and activities can provide cover for criminals to operate unnoticed. Additionally, the lack of surveillance measures such as CCTV cameras and security personnel can embolden potential thieves to target vulnerable locations where the risk of detection is lower.

In situations where there are no witnesses to deter criminal behavior or provide assistance in case of an incident, the likelihood of theft incidents occurring increases. The absence of vigilant individuals or security measures can create an environment conducive to criminal activities, especially in areas where opportunities for theft are abundant. To address these challenges, enhancing security measures such as installing CCTV cameras, increasing the presence of security personnel,

and promoting community vigilance can help deter theft and improve the overall safety of urban areas. By fostering a culture of awareness and collaboration among residents, businesses, and law enforcement, urban spaces can become more secure and less susceptible to criminal activities like theft.

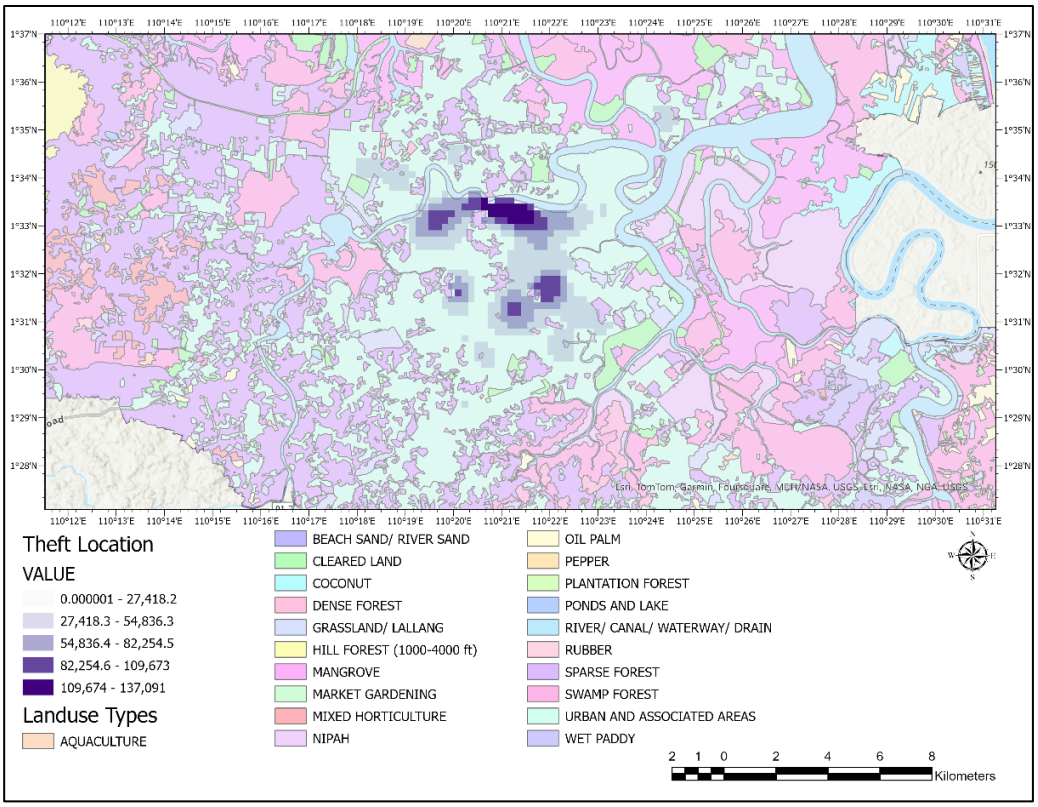

Figure 9. Kernel Density of Theft Location.

The hot spots of theft are identified using Kernel Density, as shown in Figure 9. ArcMap's automatic extraction used an output cell size of 253.8 meters and a search radius/bandwidth of zero to create the output raster. This analysis helps to pinpoint the clustering of theft locations or potential high-risk areas. There are 12 areas classified as hot spots, with theft locations having a larger concentration compared to offenders' homes. The results indicate that Sector 1 in Satok police station, Sectors 2 and 9 in Sentral police station, as well as Sectors 1, 2, 3, and 4 in Padungan police station, are identified as hot spots for theft. This suggests that theft hotspots are mainly concentrated in Padungan, indicating that criminals find easy access to these areas with high opportunities for theft. Additionally, this study detected clustering of theft in Sector 1 and 7 of Tabuan Jaya police station, and Sector 4 in Sekama police station.

When comparing the hotspots of offenders' homes and theft locations, the results reveal that certain areas overlap. Specifically, Sector 3 and 4 in Padungan police station and Sector 3 in Sekama police station show this overlap. This indicates that these areas are not only hotspots for offenders' homes but also for theft activities, highlighting a significant correlation between the locations of offenders' residences and theft incidents in these areas.

From this result, it is evident that there is a clear spatial relationship between the locations of offenders' homes and theft incidents. The overlap of hotspots in certain areas, such as Sector 3 and 4 in Padungan police station and Sector 3 in Sekama police station, suggests a concentration of criminal activity in these specific locations. This correlation implies that areas with a high density of offenders' residences also tend to experience a higher incidence of theft, indicating a potential link between the presence of offenders and criminal activities in those areas. Understanding this spatial relationship can be crucial for law enforcement agencies in developing targeted strategies to address and prevent criminal activities in these hotspots.

The overlap between offenders' homes and theft activities in certain areas of Kuching, Sarawak, indicates that offenders target locations near their residences for several reasons. These areas provide offenders with a sense of familiarity with their surroundings, making it easier for them to carry out theft activities. Moreover, these areas offer prime opportunities for theft due to various factors such as the absence of CCTV cameras and security guards, unlocked car windows or doors, instances of forcefully breaking windows, doors, or CCTV cameras, and the presence of unfenced

areas where perpetrators can easily access properties by climbing windows or fences. Additionally, offenders in these areas may utilize motorcycles to commit crimes (Kuching Police Station Report, 2018).

Furthermore, offenders' daily routines and habits often intersect with the areas near their homes, increasing the likelihood of theft incidents occurring close to their residences. This overlap suggests that offenders strategically choose locations they are familiar with, where they perceive lower risks of detection or apprehension, and where they have established connections.

5. Discussion

The result revealed that offenders in Kuching, Sarawak, tend to opt for short travel distances to commit crimes, rather than longer ones, in their decision-making process. The offenders consider the distance of their home location when choosing a crime to commit. Besides, Wiles and Costello (2000) also found that the offenders typically travel short distances when engaging in property crime. This study helps in detecting the distance between the offender's home location and the theft location. In addition, the result could also be used in a policing plan and to understand much about the offender's options in deciding on the location to commit a crime. Using the Euclidean Distance can help to detect the travel path of the thief's location and the offender's homes. These tools can also help identify potential patterns and relationships between theft location and offender homes, as they can help find a higher concentration of thefts occurring closer to certain offender residences.

This study has considered the distance between offenders' residences and the target areas. The findings indicate that distance plays a significant role in determining where offenders choose to commit theft. Offenders tend to target areas that are close to their homes or in proximity to where they reside. This indicates that offender do not travel far from their home. In addition, Ruiter (2017) did not consider the proximity of burglars' residences to the target properties, even though distance is arguably a key factor influencing the choice of burglary locations. Bernasco and Dijke (2020), who stated that a location closer to home is more attractive than a location further away. Interestingly, Snook (2004) has found that younger offenders select targets that are located near their home than older ones. According to the Kuching Police Station Report (2018), young people and those in their late twenties tend to commit crimes near their homes, within short travel distances.

This indicates a greater tendency for young adults and individuals in their late twenties to be involved in theft-related behaviors. Jubit *et al.* (2024) found that many adolescents aged 17 years or younger are addicted to drugs and reside in urban areas of the Federal Territory of Kuala Lumpur and Selangor. The study conducted by Chabo *et al.* (2022) revealed that the District Education Office of Kuching is identified as one of the hotspot areas for secondary school dropout cases between 2013 and 2018. This finding highlights a concerning trend in the education system within the Kuching district, indicating a significant number of students discontinuing their secondary education during the specified time frame. National Institute of Justice (2014) suggests that the prevalence of offending tends to follow a specific pattern across the lifespan. Studies have shown that offending behavior typically increases during late childhood, peaks during the teenage years (specifically between the ages of 15 and 19), and then declines in the early 20s in the United States. An offender who is intent on committing burglary against a commercial establishment and resides near the commercial sector in the city is unlikely to have to travel a significant distance to identify a suitable target (Snook, 2004). The urban areas in the study area are the concentrated areas of home offenders and are also becoming target areas, which indicates a higher chance of theft occurring when there are no CCTV cameras and security guards. This shows the thieves making a decision influenced by how the environment is perceived and most likely taking a short trip so that they can easily run away when found out.

The Kuching Police Station Report (2018) indicates that offenders are more likely to be apprehended when CCTV cameras are in place. This suggests that CCTV plays a significant role in preventing crime by helping to detect thieves and other criminals. This is supported by Aballe *et al*. (2022), who state that the implementation of CCTV cameras is highly effective in preventing crime. By continuously monitoring and recording activities around the clock, CCTV cameras play a crucial role in solving reported crimes like theft, robbery, and other incidents. Additionally, CCTV cameras are valuable in addressing crimes against individuals and properties, as well as in deterring traffic violations. The recorded footage from CCTV cameras serves as vital evidence in court proceedings, aiding authorities in resolving criminal cases and maintaining public safety. Besides that, the offenders are also using a motorcycle to commit theft. Law enforcement has believed for the past ten years that motorcycles are often used by criminals to commit crimes

(Bradley, 2021; Van Deuren, 2023). According to Lakeman *et al.* (2021) more and more criminals are using motorcycles to get to and escape from crime scenes, as well as to watch the area before they commit crimes. A previous study by Ainur Zaireen and Jalaluddin (2010) highlights the notion that offenders may prefer motorcycles because they provide a quick and convenient means of escape, allowing them to evade capture more easily compared to other modes of transportation.

From the Kuching police reporting systems, offenders who are unemployed and aged between 15 to 29 years old, with limited education (SPM level), are more likely to engage in theft. The finding explained that offenders tend to act alone. Charrette and Papachristos (2017) found different results in their research, indicating that criminals often work in groups. It's common to see that most crimes involve more than one person in the city of Chicago. Most criminal offenders do not act alone. The fact that the majority of criminal events involve more than one offender has been observed in many eras and geographic regions. Apart from that, Wang *et al.* (2019) found that the percentages for single offenders are higher than those for partnered offenders, and the offenders aged 18 to 34 years old have the highest percentages in the city of Toronto. In contrast, Bright (2024) found that groups of two or more co-offenders are more likely to engage in crime events involving multiple crime categories in metropolitan areas of Sydney, Australia. This study suggests that co-offenders, working together, may be involved in a wider range of criminal activities beyond just theft. The collaboration among co-offenders may enable them to carry out more complex or diverse criminal acts compared to solo offenders. Interestingly, Charrette and Papachristos (2017) discovered that the co-offending relationship becomes more robust and enduring as the number of co-offenders involved in committing crimes together increases.

The results of the mean center and SDE indicate that the size of SDE for the theft location in Kuching is smaller than that of the offender's home. It means the locations where thefts occur are more concentrated. These theft locations are clustered in a smaller, more specific area. The SDE for offenders' homes is larger, it means the residences of the offenders are more dispersed across the area. The size of the ellipse for the theft location is also concentrated in areas where offenders live. According to Jubit *et al.* (2020) crime opportunities in Kuching drive the strong global spatial patterns in residential burglary, with holidays and festivals being key contributors to increased property crime.

From the findings of this study, mostly offenders in urban areas of Kuching, Sarawak, with no job at the age of 15-29 years old and having low education (SPM level) tend to be thieves. The finding supported by Jawadi *et al.* (2021) found that a higher unemployment rate tends to increase non-violent crime, suggesting a correlation between economic factors and crime rates. When individuals face unemployment and financial hardship, they may resort to criminal activities for survival or to maintain their standard of living.

Other researchers used SDE to analyze crime, such as Ahmad *et al.* (2024), who used mean center and standard deviation ellipses (SDE) to analyze property crime during midnight, morning, evening, and night from 2015 to 2020 in Selangor and Kuala Lumpur. The finding shows that the size of the SDE for night is larger than at midnight. This indicates that the property crime at midnight tends to be clustered as the SDE size becomes smaller, while the property crime at night is more dispersed as the size is greater. The property crime in Kuala Lumpur and Selangor is mostly concentrated in residential areas, commercial zones, and institutional facilities. Several factors influence property crime in urban areas. Apart from that, Almond *et al.* (2024) were using Euclidean distance to understand the distance an offender travels from their home to the crime location. The study found that when it comes to stranger sexual assaults, the place where the offender first approached the victim was found to be much farther away from where the offender lived.

The finding is also very related to the Routine Activity Theory. This theory focuses on the convergence of three factors: motivated offenders, suitable targets, and the absence of capable guardians (Cohen *et al.*, 2010). The statement describes a population of young individuals with limited employment opportunities and low education levels, who could be considered motivated offenders. The urban environment of Kuching could provide suitable targets for theft, and the lack of employment and social cohesion in these areas could contribute to the absence of capable guardians. This combination of factors increases the likelihood of criminal activity.

The study only includes theft cases that have been reported to the Police Reporting System. The data does not account for offenders who were not arrested or identified. This could lead to an underrepresentation of the actual number of thefts and offenders. The dataset may lack comprehensive demographic information about offenders, which could limit the analysis of patterns related to age, gender, race, or other relevant factors. The future research could use the theft location and offenders home within more than three years to see the patterns. Future studies should focus

on understanding the complexity of offender travel patterns, considering factors like multiple destinations, travel companions, and the use of public transportation.

6. Conclusion

Geographic Information Systems (GIS) play a crucial role in identifying the proximity of offenders' homes to theft locations and detecting spatial patterns of property crime. This valuable tool aids the Royal Malaysian Police, especially in Kuching, in addressing crime within specific police station sectors effectively. GIS is instrumental in pinpointing the modus operandi used by offenders in committing crimes in particular areas. Moving forward, it is essential for the Royal Malaysian Police to document the details of the modus operandi in each reported crime, as not all cases provide this information. Urban planners can leverage this data to strategically place CCTV cameras and implement the safe city concept in Kuching to reduce crime rates. Analyzing modus operandi by location is a pivotal strategy in combating and managing urban crime.

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Author Contributions

Conceptualization: Jubit, N., Masron, T., Soda, R., Ahmad, A., & Nordin, M. N; **methodology**: Jubit, N., Masron, T., Soda, R., Ahmad, A., & Nordin, M. N; **investigation**: Jubit, N., Masron, T., Soda, R., Ahmad, A., & Nordin, M. N; **writing—original draft preparation**: Jubit, N., Masron, T., Soda, R., Ahmad, A., & Nordin, M. N; **writing—review and editing**: Jubit, N., Masron, T., Soda, R., Ahmad, A., & Nordin, M. N; **visualization**: Jubit, N., Masron, T., Soda, R., Ahmad, A., & Nordin, M. N. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

Data availability

Data is available upon Request.

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