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EXPLORING THE POTENTIAL OF GEOGRAPHIC INFORMATION SYSTEM (GIS) APPLICATION FOR UNDERSTANDING SPATIAL DISTRIBUTION OF VIOLENT CRIME RELATED TO UNITED NATIONS SUSTAINABLE DEVELOPMENT GOAL-16 (SDG-16)

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Abstract: The achievement of Sustainable Development Goal (SDG) 16, which promotes peace, justice, and strong institutions, is significantly hindered by the prevalence of violent crime, particularly gang violence and interpersonal violence, a situation that is especially acute in resource-limited developing nations. This study investigates the application of Geographic Information Systems (GIS) as a strategic tool to bolster the efforts of the Royal Malaysia Police (RMP) and local authorities (PBT) in Selangor, Kuala Lumpur (KLFT), and Putrajaya (WFT), Malaysia, in their fight against violent crime. This research meticulously maps crime hotspots and analyses the interplay between crime incidence and enabling a data-informed approach to crime prevention. Moreover, it evaluates the challenges developing nations encounter in harnessing such technological advancements, focusing on potential collaborations with private entities like Google and Alibaba to enhance the efficacy of GIS technologies in realising SDG-16. This research is expected to reveal the significant potential of GIS in identifying crime hotspots and delineate the obstacles developing countries face in adopting technology. By highlighting the constructive role of private-sector partnerships in fostering these advancements, the research contributes to SDG-16's objective of building peace, justice, and strong institutions, thereby supporting the overall sustainable development agenda.

Keywords: Crime hot spot mapping, Geographic Information System (GIS), Spatial Analysis, Sustainable Development Goal-16 (SDG-16), violent crime.

Introduction

Understanding the geographical patterns of violent crime is critical, especially in the context of the United Nations Sustainable Development Goals (SDGs), particularly Goal 16 (Figueiredo & Mota, 2016; Li & Sun, 2018; Shenoy *et al.,* 2021; Singh & Olofinbiyi, 2022; Nyussupova *et al.,* 2023). Geographic Information System (GIS) offers valuable tools for identifying and analysing crime hotspots, thereby aiding targeted interventions (Zhang et al., 2006; Silva *et al.,* 2020). GIS is becoming increasingly important for understanding the geographical patterns of violent crime. This is especially true in rapidly growing urban areas like Selangor, Kuala Lumpur, and Putrajaya, Malaysia. In these regions, the rise of gang violence and interpersonal conflicts demands innovative approaches to crime prevention and law enforcement. GIS technology offers a powerful tool for this purpose. By analysing crime data geographically, GIS can help visualise crime hotspots and identify areas experiencing disproportionate levels of violence (Folharini *et al.,* 2023). However, the literature lacks a comprehensive exploration of how GIS can mitigate the effects of limited financial resources on data collection efforts, particularly in regions like Selangor, Kuala Lumpur, and Putrajaya,

where violent crime is a pressing concern. This is of relevance in Malaysian states like Selangor, Kuala Lumpur, and Putrajaya, where violent crime is of significant concern (Abdul Rahman & Abd Razak, 2021; Chen *et al.,* 2021).

Studies have shown that hotspot interventions have a stronger impact on violent crime compared to other types of crime (Cusimano *et al.,* 2010; Braga *et al.,* 2012; Cummings *et al.,* 2019; Weisburd *et al.,* 2019; Xiong & Luo, 2020; Brenner, 2022; Haley *et al.,* 2023). GIS serves as a valuable tool not only for identifying risk factors and hotspots but also facilitates collaboration among various stakeholders to design effective prevention strategies (Anser *et al.*, 2020; Waller, 2021). This article aims to explore the spatial and temporal dimensions of violent crimes in Selangor, Kuala Lumpur, and Putrajaya from between 2015 and 2020, thereby assisting in achieving SDG-16 and enhancing community safety post COVID-19.

Despite the acknowledgement of GIS' utility in identifying crime hot spots and aiding targeted interventions, there remains a gap in understanding how GIS can address these data collection challenges in resource-constrained environments. The study addresses a critical problem within the context of Sustainable Development Goal (SDG) 16, focusing on peace, justice, and strong institutions, particularly in resource-constrained developing countries like Malaysia. While GIS technology offers promising tools for identifying and analysing crime hotspots, the timely issue lies in the challenges faced by developing nations in effectively adopting and implementing such technology. Evidence from the literature highlights the relevance of GIS in understanding spatial distribution and patterns of violent crime, which is crucial for law enforcement agencies in areas like Selangor, Kuala Lumpur, and Putrajaya, where violent crime is a significant concern. Notably, the lack of research in integrating GIS with SDG-16 in developing countries like Malaysia underscores a notable gap in the current research landscape. However, while the potential benefits of GIS in understanding the spatial distribution of violent crimes are well-documented, the literature often overlooks its role in mitigating the challenges faced by developing nations in collecting high-quality data, particularly within the framework of Sustainable Development Goal (SDG) 16.

In conclusion, while the literature has extensively documented the efficacy of GIS in crime analysis, there exists a significant gap in understanding how GIS can address data collection challenges in developing nations, particularly within the framework of SDG-16. By addressing this gap, future research can contribute to a more comprehensive understanding of the role of GIS in promoting peace, justice, and strong institutions in resource-constrained environments.

Literature Review

The use of Geographic Information Systems (GIS) for studying crime hotspots has dramatically improved understanding where and why crimes happen. A few researchers showed that GIS helps to see patterns of crime across different places (Önden *et al.,* 2014; Newton, 2015; Cabrera-Barona *et al*., 2019; Smith & Onésimo Sandoval, 2019; He *et al*., 2020). A popular method in this field, the Getis-Ord Gi* statistic, is widely used to find out where crime hotspots are located (Newton, 2015; Cummings *et al.,* 2019; Smith & Onésimo Sandoval, 2019; Wang *et al.,* 2020; Yuan *et al.,* 2022). This information is beneficial for the police because it helps them ascertain where to focus their efforts (Twinam, 2017). GIS is also important for tracking the progress of Sustainable Development Goals (SDGs), helping police improve community development (Scientific Advisory Board, 2016; Avtar *et al.,* 2020). It offers many benefits, like collecting data and solving problems related to where crimes happen, which helps make decisions and plan for a sustainable future (Campagna, 2006; Cheney, 2019; Kumar *et al.,* 2019). However, a study by Nabiyeva & Wheeler, (2020) found that there are very few articles (only 0.06% or

four articles) published since 2015 that talk about violent crimes, GIS, and SDG-16. Also, in Malaysia, the focus has been more on creating DNA databases and dealing with illegal logging, with little attention to studying crime through GIS (Mohd Hakim *et al.*, 2019; Mun *et al.,* 2019; Mohd Noor *et al.,* 2021). This shows there needs to be more research in this area, even though it is essential. In simple terms, although GIS has shown great promise in helping understand and reduce crime and in supporting the goals for a better world, there is still much work to be done, especially in countries like Malaysia. There is a need for more research that looks at violent crimes using GIS to help achieve SDG-16, which aims for peace, justice, and strong communities.

Aogo *et al.* (2021) demonstrated how GIS can aid security agencies in planning, allocating resources effectively, and analysing crime patterns to reduce incidences in the study area, thereby contributing to sustainable development. Mohammed & Baiee, (2020) research identifies crime mapping and hotspot analysis as crucial for law enforcement in developing countries to detect spatial crime patterns and predict future crimes. Tom-Jack *et al.,* (2019) focus on the identification of linear statistically significant spatial crime clusters at the street level to assist law enforcement agencies with targeting efforts more precisely. A study by Fitterer *et al*. (2015) illustrates the potential for GIS to assist police patrols and resource deployment based on GIS crime predictions. This research explores the concept of "harm spots," areas with clusters of harm-weighted crimes, suggesting different socio-ecological processes might underlie the spatial distribution of more serious crimes (Fenimore, 2019). Research by Sheikh *et al.,* (2017), highlights the importance of GIS in crime analysis and the advancement of investigative strategies for policing, contributing to the development of safer city strategies.

Research from around the world shows that geographical information systems (GIS) are beneficial for understanding crime hotspots better. In Malaysia, studies by Jubit *et al*. (2019), (2020), (2021); Jubit & Masron, (2022); Masron *et al.* (2021) have shown that GIS can find where property-related crimes like burglaries and break-ins are more likely to occur. These studies, and others from different countries, show that police are using GIS to work smarter and keep communities safer by knowing where to focus their efforts.

Jubit *et al*. (2019; 2020); and Masron *et al.,* (2021) shed light on its multifaceted impact and showed how GIS can spot where property crimes are happening by looking at the patterns of where these crimes occur. They used a unique method called Getis-Ord Gi* to find these crime hotspots. This approach shows that GIS is not just about making maps; it is a powerful tool that can help police decide where to send officers and how to prevent crime. Jubit *et al.,* (2020) also talked about how important it is to look at crime from where it happens, especially in cities where certain areas might have more break-ins. This helps police not only to focus on these areas but also to understand why these places might be targeted more. Masron *et al.,* (2021) took this idea further by showing how GIS can help with community policing. By looking at crime trends in different areas, they showed how GIS helps police use their resources wisely and produce plans that consider the specific needs of different communities. All these studies together highlight the growing use of GIS in policing. By knowing where crimes are more likely to happen, police can allocate resources more effectively and make communities safer through careful planning and targeted actions.

According to Reitano & Hunter, (2018) study focuses on the complex relationship between crime, business, and politics in Africa and its impact on development. It highlights the need for political economy analysis to understand and respond to the threat of organised crime. Development assessments in various sectors, such as conflict, governance, and public health, should include organised crime analysis. The study also emphasises the role of corruption, impunity, and lack of ethics in contributing to rising levels of organised crime. Additionally, it

discusses the increasing reliance on smugglers for migration due to restricted legal channels and the profitable nature of human smuggling. The study suggests that development actors need to understand how organised crime affects their objectives and programming to identify and mitigate its impact on development.

Meanwhile, a study by Santos, (2021) is about the relationship between sustainable development goals (SDGs), public policies for mitigating violence, and the right to a safe city. They argue that cities are the main places where violence occurs, and therefore, policies for reducing violence should be focused on cities. The SDGs can serve as a framework for these policies. The articles also highlight the need for a shift from macrocosmic to microcosmic approaches in diagnosing and addressing violence, with a focus on disadvantaged neighbourhoods. They emphasise the failure of national-level policies and the importance of localised strategies. The articles also discusses the factors contributing to urban violence, such as unregulated urban growth and socioeconomic disadvantage. They highlight the multifactorial nature of violence and the need for comprehensive approaches to understanding and addressing it.

Research by United Nations Geospatial Network, (2021), discusses the importance of geospatial information in supporting the measurement and monitoring of the Sustainable Development Goals (SDGs) outlined in the 2030 Agenda for Sustainable Development. It emphasises the role of the United Nations in providing reliable global geospatial information to support decision-making and address the priorities set out in the United Nations Charter and global agendas. The study mentioned in the article highlights the rising income inequality and its association with growing spatial disparities. It emphasises that inequalities based on gender, ethnicity, race, place of origin, and socioeconomic status largely determine the opportunities individuals can get. The study also reveals that the richest 1 per cent in the world own 40 per cent of the world's household wealth, which is greater than the wealth of the world's poorest 95 per cent. It highlights the need for reliable data on income inequality, especially at a sub-national level, to develop tailored policies and strategies to address inequalities.

The study by SDG-16 Hub, (2022) focuses on the development and implementation of the SDG-16 Survey, which is a survey that was initiative, and is related to Sustainable Development Goal 16 (SDG-16) on peace, justice, and strong institutions. The study aims to gather data on various indicators related to SDG-16, such as access to justice, discrimination, violence, bribery, corruption, and human trafficking. The survey is designed to provide information on the overall accessibility of civil justice institutions and processes, as well as the barriers faced by individuals in enforcing or defending their rights. The study emphasises the importance of international comparability and the inclusion of optional standard items to ensure the relevance and usefulness of the survey data. The survey implementation involves different phases, and the study provides a generic survey timeline for planning purposes. The study also highlights the modular design and dimensions of survey quality as key considerations in the implementation of the SDG-16 Survey.

While Geographic Information Systems (GIS) has the potential to help achieve Sustainable Development Goal (SDG) 16, which focuses on peace, justice, and strong institutions, there needs to be more in using it, especially in developing countries. Studies on Malaysia's Safe City program mainly look at minor crimes through local community policing (Nordin & Mohd Saad, 2010; Mun *et al.,* 2019). Several challenges have made it hard to use GIS effectively. These include money problems made worse by the COVID-19 pandemic, changes in government policies after the 2018 election, and trouble getting the detailed location data needed for GIS (Altaweel, 2019; Mun *et al.,* 2019).

To deal with these issues, the United Nations has started working with big companies like Google and Alibaba. These companies can

provide support and resources that can help countries meet their SDG goals. This kind of partnership could solve problems with regards to getting data and needing more money for high-quality research. By working together and getting better data, GIS can be used more effectively to create plans that focus on increasing safety and stability, which is essential for reaching SDG-16 by 2030. Keeping an eye on violent crime over time is critical to see how well these efforts are working (Uittenbogaard & Ceccato, 2012).

Materials and Methods

Study Area & Spatial Data

This study focuses on Selangor, Kuala Lumpur Federal Territory (KLFT), and Putrajaya Federal Territory (PFT), regions in Malaysia that are known for their distinct demographic and economic profiles (Department of Statistics Malaysia, 2020; Economic Planning Unit, 2022). Employing a quantitative approach, the research utilises secondary data on violent crime statistics from 2015 to 2020, sourced from the Criminal Investigation Department (D4), Bukit Aman. Key variables like address, time, and crime index are included in the data set. The data is spatially analysed and aggregated at the police station boundary level using ArcGIS software. It shows the importance of ESRI's ArcGIS software including ArcCatalog, ArcScene, ArcGlobe, web-based with ArcGIS Online and ArcGIS Pro, especially ArcMap to help analyse this research (Ahmad *et al.,* 2011, 2013, 2015, 2024a; Azizul & Tarmiji, 2013; Norizawati *et al.,* 2013, 2014; Basiron *et al.,* 2014; Azizan *et al.,* 2023; Jubit *et al.,* 2023a; Zakaria *et al.,* 2023; Ariffin *et al.,* 2024). Specifically, the study examines boundaries in IPK Selangor, featuring 87 police stations, and IPK Kuala Lumpur with 24 stations (Jubit *et al.,* 2022; Jubit *et al.*, 2023b; Ahmad *et al.,* 2024b, 2024c, 2024d). This boundary-level approach enhances the focus and effectiveness of crime prevention strategies (Braga *et al.,* 2012; Weisburd & Telep, 2014; Inlow, 2021).

Violent Crime and Hot Spot Analysis Statistic (Getis-Ord Gi)*

The study employs GIS and Getis-Ord Gi* statistics to analyse the spatial patterns of violent crime in Selangor, KLFT, and PFT, contributing to the realisation of SDG-16 (Kogure & Takasaki, 2019; Winarta *et al.,* 2021). GIS serves as a robust platform for collecting, structuring, and visualising spatial data, including variables like population density and land use (Smith & Onésimo Sandoval, 2019; Wang *et al.*, 2020; He *et al.*, 2022; Yuan *et al.*, 2022; Zhu *et al.*, 2022; Costantini & Thompson, 2023). The Getis-Ord Gi* statistic identifies hotspots of violent crime and provides valuable information into regions where crime events cluster (Meisch *et al.,* 2019; Wang *et al.*, 2020; Costantini & Thompson, 2023). This methodology enables targeted interventions by identifying high-crime areas, thereby aligning with the objectives of SDG-16 (Güven & Gerçek, 2018; Shenoy *et al.,* 2021). The Getis-Ord Gi* statistic is calculated using the following equation:

$$\mathbf{G_i^*} = \frac{\sum_{j=1}^{n} \mathbf{W_{i,j}X_j} - \bar{\mathbf{x}} \sum_{j=1}^{n} \mathbf{W_{i,j}}}{\mathbf{S}\sqrt{\frac{\left[\mathbf{n}\sum_{j=1}^{n} \mathbf{W_{i,j}^2} - \left(\sum_{j=1}^{n} \mathbf{W_{i,j}}\right)^2\right]}{\mathbf{n-1}}}} \quad (1)$$

Results are validated through z-scores and p-values, which indicate the statistical significance of observed spatial clustering (ArcGIS Pro 3.1, 2022a, 2022b, 2022c; ArcMap 10.8, 2022). The analysis thus provides a robust framework for understanding and combating violent crime spatially (Watters, 2016).

Global Moran's I (Spatial Autocorrelation)

Global Moran's Index was employed to distinguish between distributed, random, or clustered instances of violent crime in Selangor, Kuala Lumpur, and Putrajaya. Calculated by averaging the observed data, Moran's Index correlates each incident's value with the values of other incidents. When the calculated Moran's Index is found to be significant, z-scores and p-values are presented to validate the significance of the spatial patterns (Mohamad Rasidi *et al.,* 2013; Ariffin 2022). This index,

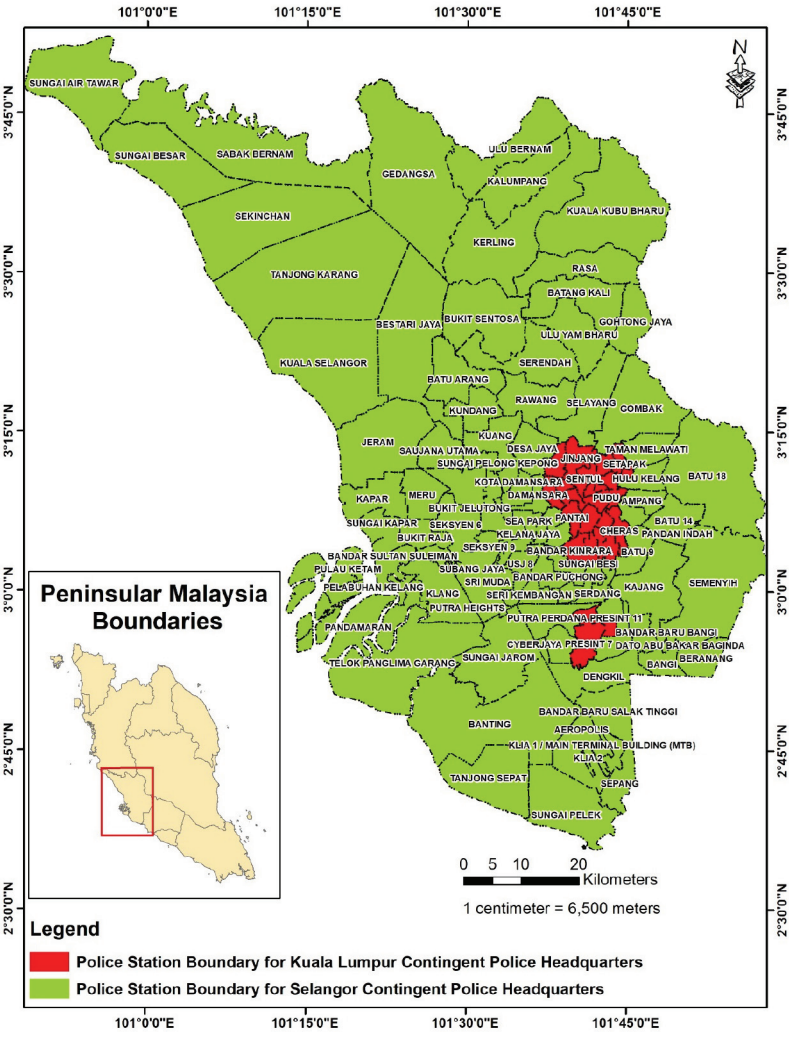

Figure 1: Study area
Source: Data Collection/Analysis Division, Crime Prevention and Community Safety Department (JPJKK), Royal Malaysian Police Headquarters, Bukit Aman

denoted as Spatial Autocorrelation (SA), measures the strength of spatial relationships between objects or polygons with a correlation coefficient ranging between I = -1 and +1. Values close to 0 indicate random patterns, whereas +1 represents the strongest positive spatial autocorrelation approaching clustering, and -1 indicates the strongest negative spatial autocorrelation approaching dispersion. The analysis yields the Global Moran's I index value, along with z-scores, p-values, and other metrics to gauge its significance.

If both the z-score and p-value are less than 0.05, the null hypothesis is rejected, indicating the presence of spatial autocorrelation. However, this approach does not identify specific clustering areas and spatial patterns. To assess localised spatial relationships and identify affected areas, the Getis-Ord Gi* technique is applied (Ariffin, 2022). A p-value, a numerical representation of the area under the curve for a known distribution, confirms the significance of the spatial test (Townsley, 2009; Zheng, 2021; ESRI, 2022). In

this research, exploratory analysis, or SA, aids in the spatial statistical identification of violent crime. This method examines closely related subjects that might share more similarities than expected, yielding a properly clustered, dispersed, or random geographical distribution (Figure 2). The SA measures and delineates two levels of observations (values) present at specific locations and will identify similarities between them. Both exogenous and endogenous factors can be included in this study (ESRI, 2022). The analysis aims to understand the spatial and temporal patterns of criminal behaviour in Selangor, KLFT, and PFT.

Calculated using Moran's I statistic and column autocorrelation as shown in equation 2 below:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{i,j} Z_i Z_j}{\sum_{i=1}^{n} Z_i^2} \quad (2)$$

Where n is the total number of features, Z_i is the attribute deviation for feature i from the mean (x_i-X), w_{ig} is the spatial weight between i and j, and S_0 is the sum of all spatial weights:

$$\overline{S_0} = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{i,j} \quad (3)$$

The z-score for the statistic was calculated as

$$Z_I = \frac{I - E[I]}{\sqrt{V[I]}} \quad (4)$$

$$E[I] = -1/(n-1) \quad (5)$$

$$V[I] = E[I^2] - E[I]^2 \quad (6)$$

where:
s^2 is the sample variance
i and j are column index units
y is a variable value for each specific location
y_i and y_y are overall means
W_{ij} is the weighted location index of the associated i
$_i$ is the mean of y
n is the sum or number of points or polygons

Results and Discussion

Descriptive Analysis

Based on Table 1 below, violent crimes were the most reported type of case in 2017 with 11,671 cases, which accounted for 20.38% of the total for that year. Meanwhile, 2020 had the lowest number of reports with 8,008 incidents which accounted for 13.98% of the total for that year. An increase in violent crimes was reported in 2016 and 2017. While in the period from 2018 to 2020, there was a decrease in the number of cases by -4.37%, -0.7%, and -1.33%. This decrease accounted for a total of 1,663 violent crimes. There are typically eight types of violent crimes. These include those under Section 302 of the Penal Code (murder), Sections 324, 325, and 326 of the Penal Code (causing injury), Section 376 of the Penal Code (rape), Section 392 of the Penal Code (unarmed bandits, Sections 392/397 of the Penal Code (armed bandits), Section 395 of the Penal Code (group of bandits without firearms) and Section 395/397 of the Penal Code (group of bandits with firearms).

Global Moran's I (Spatial Autocorrelation)

The analysis of spatial autocorrelation using Global Moran's I provides valuable insights into the distribution of incidents involving violent crimes within Selangor, Kuala Lumpur, and Putrajaya from 2015 to 2020. Table 2 and Figure

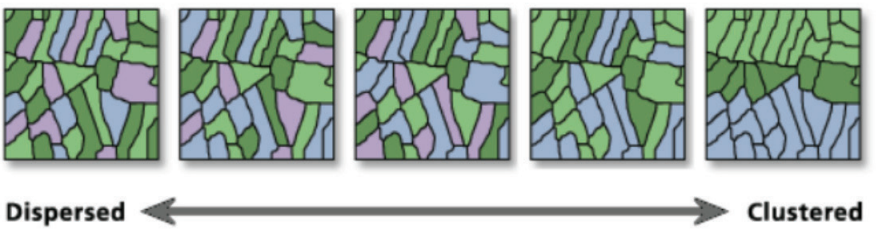

Figure 2: Spatial Autocorrelation (SA)
(ESRI, 2022)

Table 1: Total violence and percentage in Selangor, Kuala Lumpur, and Putrajaya in 2015-2020

Year/Type	Violent Crime	Percentage	Number of Drops	Percent Decrease
2015	9,671	16.89	0	0
2016	9,988	17.44	317	0.55
2017	11,671	20.38	1,683	2.94
2018	9,168	16.01	-2,503	-4.37
2019	8,769	15.31	-399	-0.7
2020	8,008	13.98	-761	-1.33
Total/Percent	**57,275**	**100**	**1,663**	**100**

Source: Intelligence/Operations/Records, Criminal Investigation Department D4-Division JSJ, Bukit Aman

3 showcase the results of this analysis, shedding light on the spatial patterns and correlations between violent crimes over the study period. Table 2 and Figure 3 collectively indicate that the year with the highest z-score, 14.5257708863, is 2017, reflecting a pronounced clustering of violent crimes during that period. Conversely, the lowest z-score of 5.96100363892 was observed in 2020. This disparity in z-scores underscores the variations in spatial distribution, with 2020 demonstrating a less intense clustering pattern. Importantly, the z-scores are accompanied by p-values, all of which are less than 0.01%, reinforcing the statistical significance of the observed clustering pattern. This implies that the spatial patterns of violent crime between 2015 and 2020 are not random occurrences, but rather structured clusters.

The application of Global Moran's I for spatial autocorrelation analysis offers a powerful tool for understanding the interplay between SDG-16 and the occurrence of violent crime. The clustering patterns of violent crime that have been observed implied that specific interventions may be necessary in these areas to improve safety and reduce crime rates, in line with the goals of SDG-16. This positive spatial autocorrelation underscores the importance of targeted strategies to address crime in localised regions. Through the lens of Global Moran's, I, this study examines whether the implementation of SDG-16 has a discernible impact on violent crimes. By assessing spatial clustering or dispersion of violent crime incidents, the analysis delves into the effectiveness of SDG-16 in curbing violent crimes. This approach offers a novel perspective on how SDG-16's goals of promoting peace, security, justice, and inclusive institutions manifest in the geographical distribution of violent crimes.

Table 2: Global Moran's I (Spatial Autocorrelation) for violent crime polygons/areas from 2015 to 2020 in the States of Selangor, Kuala Lumpur, and Putrajaya

Year	Moran's Index	Expected Index	Variance	Z score	P value	Pattern	Distance Threshold (m)
2015	0.153106	-0.009091	0.000529	7.050488	0.000000	Clustered	20043.2801
2016	0.204086	-0.009091	0.000532	9.242405	0.000000	Clustered	20043.2801
2017	0.322222	-0.009091	0.000520	**14.525771**	0.000000	Clustered	20043.2801
2018	0.273915	-0.009091	**0.000536**	12.220131	0.000000	Clustered	20043.2801
2019	0.187606	-0.009091	**0.000513**	8.683483	0.000000	Clustered	20043.2801
2020	0.128652	-0.009091	0.000534	**5.961004**	0.000000	Clustered	20043.2801

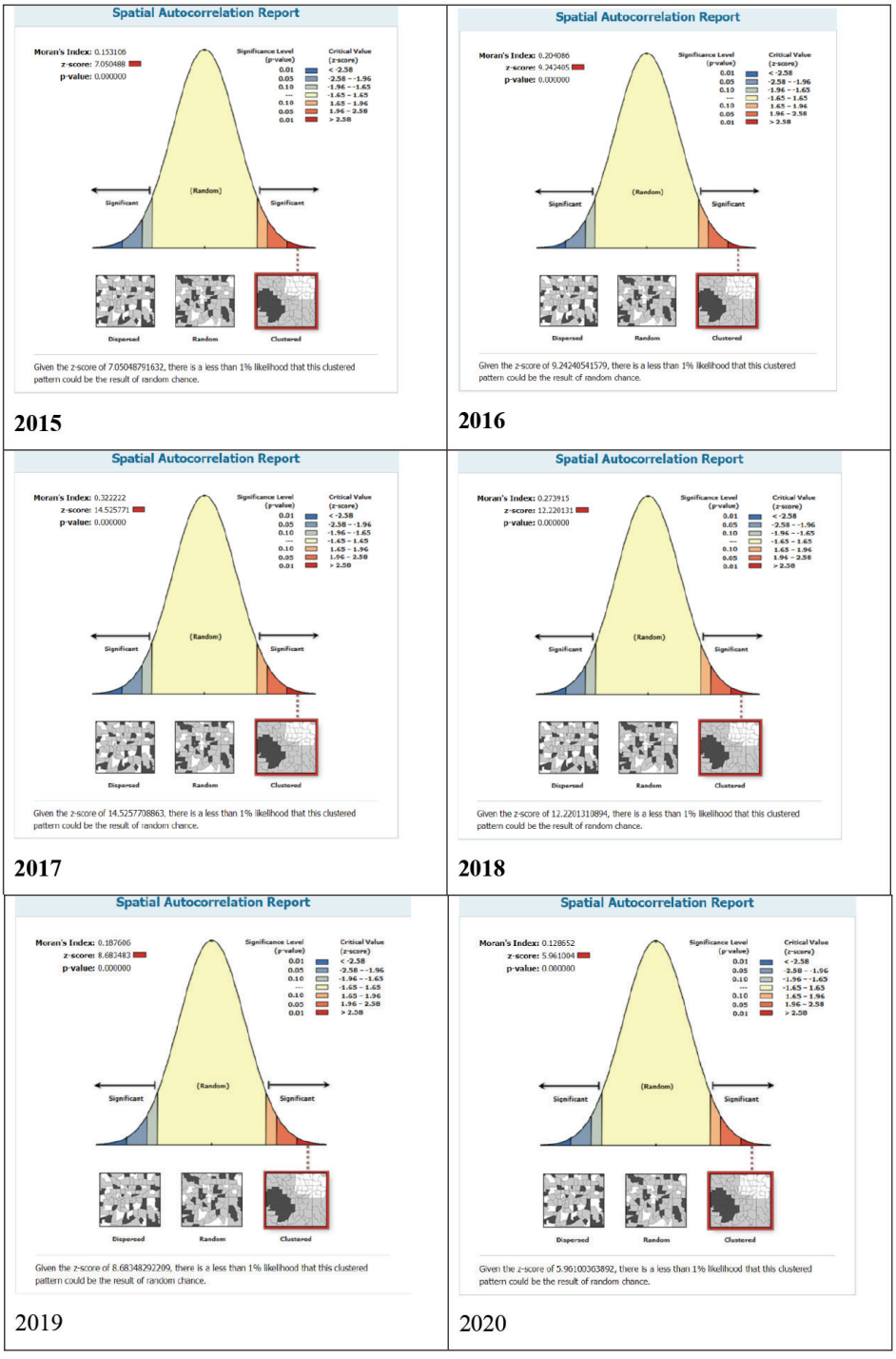

Figure 3: Graf for Global Moran's I (Spatial Autocorrelation)

Moreover, the insights drawn from Global Moran's I analysis facilitate the identification of potential hotspots requiring specialised interventions. This information empowers policymakers to allocate resources strategically for community engagement, crime prevention, and law enforcement initiatives. The implications of addressing violent crimes extend beyond law enforcement, affecting public safety, economic growth, tourism, social cohesion, and overall community well-being. In summary, the application of Global Moran's I to analyse the impact of violent crimes within the framework of SDG-16 yields a data-driven approach to understanding spatial crime patterns. This analysis empowers policy interventions aimed at fostering peace, security, justice, and inclusive institutions. By combining geographical insights with development goals, this study contributes to the collective effort of building safer and more inclusive communities.

Hot Spot Analysis Statistic (Getis-Ord Gi)*

The Hot Spot Analysis Statistic (Getis-Ord Gi*) provides a detailed examination of the distribution of violent crimes across police station jurisdictions within Selangor, Kuala Lumpur, and Putrajaya between 2015 and 2020. The analysis, presented in Table 3, Table 4, and Figures 4 and 5, reveals significant insights into the spatial clustering of violent crimes, supported by a confidence level of between 90% and 99%. Between 2015 and 2016, the analysis encompasses 50 police station jurisdictions, comprising 22 in Kuala Lumpur and 28 in Selangor. The following year, 2017, marked an increase to 51 police station jurisdictions, including 22 in Kuala Lumpur and 29 in Selangor. In 2018, this trend continued, as it involved 52 police stations, with 22 situated in Kuala Lumpur and 30 in Selangor. A slight reduction was recorded in 2019 involving 49 police stations, 22 in Kuala Lumpur and 27 in Selangor. Finally, in 2020, the analysis covers a total of 49 police stations, comprising 22 in Kuala Lumpur and 27 in Selangor.

Table 3: Hot Spot and Police Station Boundary

No	Year	Kuala Lumpur	Selangor
1	2015	22	28
2	2016	22	28
3	2017	22	29
4	2018	22	30
5	2019	22	27
6	2020	22	27

The results for the Hot Spot analysis spanning between 2015 and 2020, which includes 50 police stations revealed that there are 22 police stations in Kuala Lumpur and 28 in Selangor. The police stations in Kuala Lumpur include Brickfields, Pantai, Petaling, Sri Hartamas, Sri Petaling, Taman Tun Dr. Ismail, Travers, Bukit Jalil, Cheras, Salak Selatan, Salak Selatan Baru, Sungai Besi, Chow Kit, Dang Wangi, Tun H. S. Lee, Jinjang, Kepong, Sentul, Jalan Tun Razak, Pudu Setapak, and Wangsa Maju. Meanwhile for the Selangor Contingent, the police stations include Ampang, Hulu Kelang, Pandan Indah, Taman Melawati, Desa Jaya, Gombak, Rawang, Selayang, Batu 14, Batu 9, Kajang, Damansara, Kelana Jaya, Kota Damansara, Lapangan Terbang Sultan Abdul Aziz Shah (LTSAAS), Petaling Jaya, Sea Park, Sri Damansara, Sungai Way, Seri Kembangan, Serdang, Puchong, Bandar Kinrara, Bandar Sunway, Subang Jaya, USJ 8, Kampung Baru Subang, and Sungai Buloh. The reason that Kuala Lumpur and Selangor have the highest violent crimes rates which is attributed to several factors, including urbanisation, population density, financial inequality, social disorganisation, and police presence.

Table 5 shows that the highest z score is in the year 2017, while the lowest z score is in the year 2019. Hot spot analysis sometimes referred to as Getis-Ord Gi* statistics, is used to identify regions where a specific occurrence tends to cluster or concentrate. The use of Hot Spot analytics can provide insights into the prevalence of violent crimes and how it relates to SDG-16, one of the United Nations Sustainable Development Goals that aims to promote an inclusive and peaceful society. By analysing

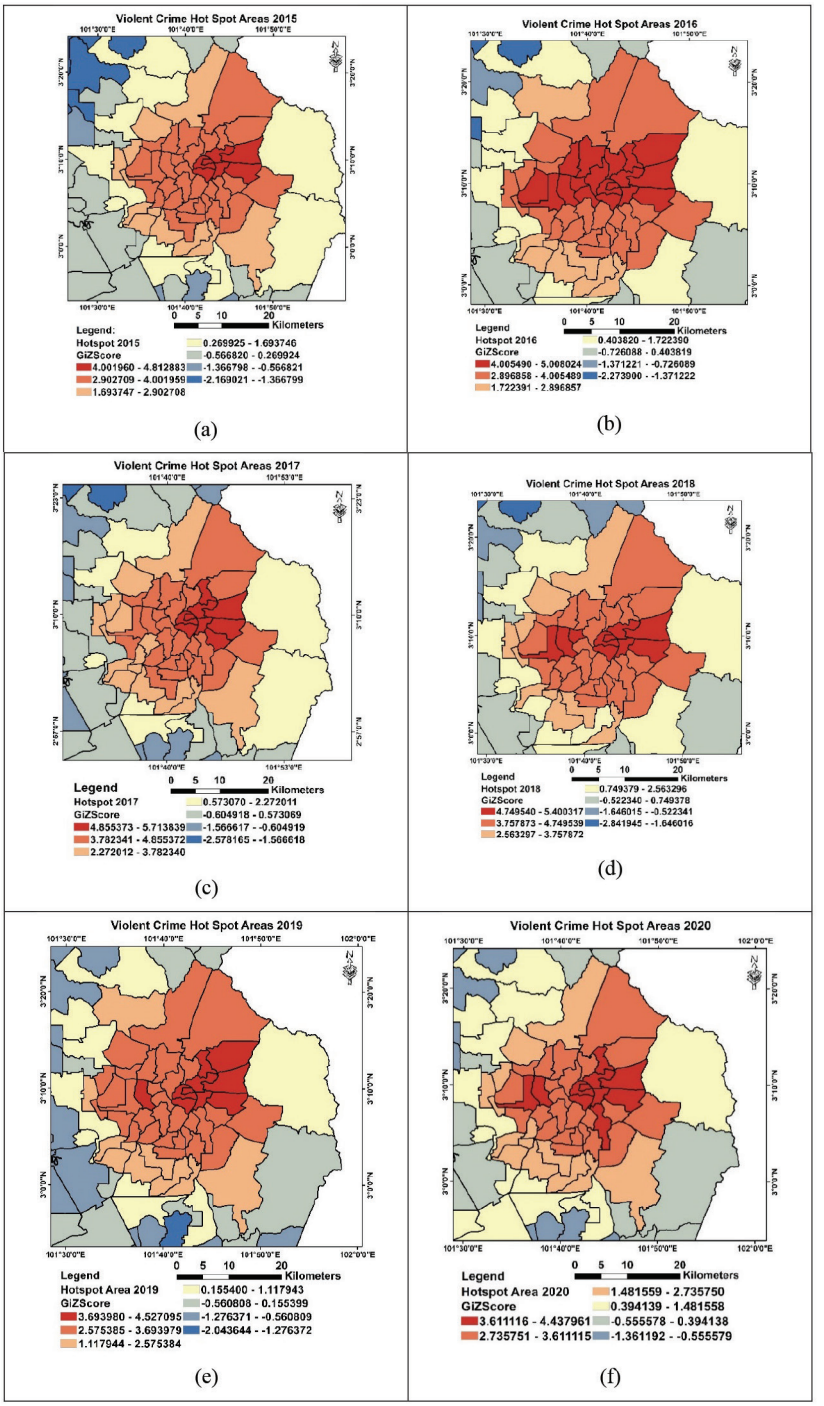

Figure 4: Hot Spot Analysis for violent crime 2015-2020 using (Getis-Ord Gi*)

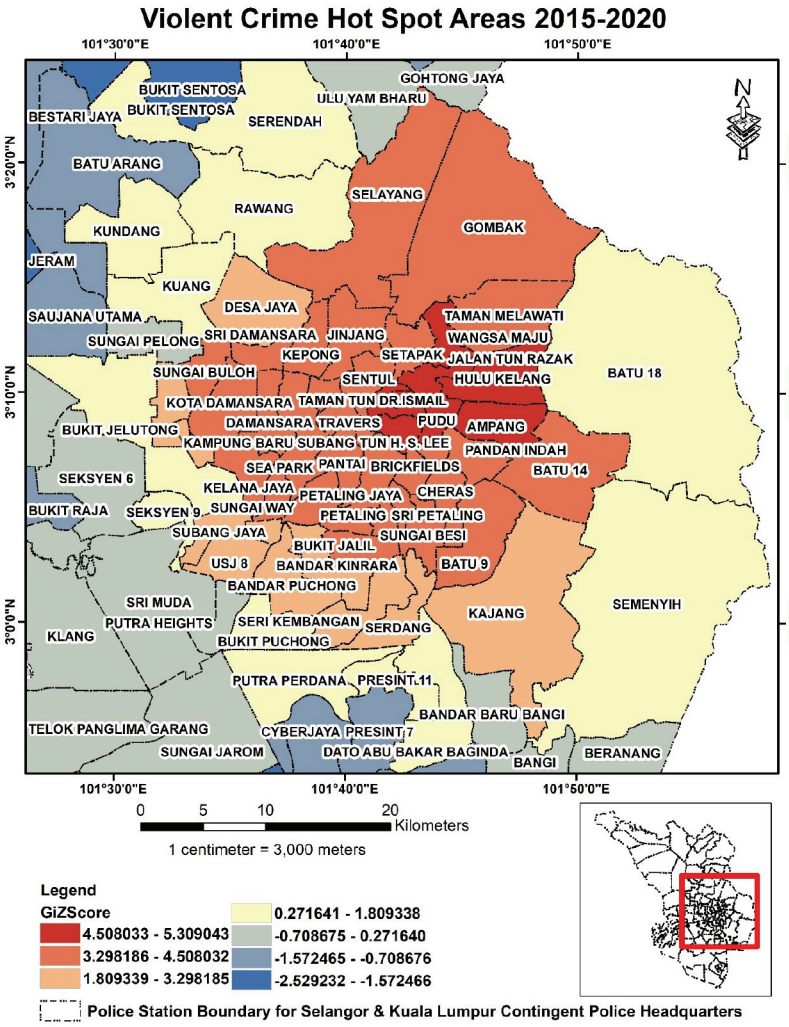

Figure 5: Analysis of Spatial Clustered (Hot Spot Area) Year 2015 to 2020 According to Polygon/Area based on the Overall Report of Violent Crime Cases

Table 4: Relationship Between Violent Crime Hot Spot Areas & Police Station Boundaries with 90% to 99% Confidence Levels

NO.	IPK	IPD	BALAI POLIS	2015	2016	2017	2018	2019	2020	2015-2020
1	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS BRICKFIELDS	X	X	X	X	X	X	X
2	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS PANTAI	X	X	X	X	X	X	X
3	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS PETALING	X	X	X	X	X	X	X
4	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS SRI HARTAMAS	X	X	X	X	X	X	X

NO.	IPK	IPD	BALAI POLIS	2015	2016	2017	2018	2019	2020	2015-2020
5	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS SRI PETALING	X	X	X	X	X	X	X
6	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS TAMAN TUN DR. ISMAIL	X	X	X	X	X	X	X
7	KUALA LUMPUR	BRICKFIELDS	BALAI POLIS TRAVERS	X	X	X	X	X	X	X
8	KUALA LUMPUR	CHERAS	BALAI POLIS BUKIT JALIL	X	X	X	X	X	X	X
9	KUALA LUMPUR	CHERAS	BALAI POLIS CHERAS	X	X	X	X	X	X	X
10	KUALA LUMPUR	CHERAS	BALAI POLIS SALAK SELATAN	X	X	X	X	X	X	X
11	KUALA LUMPUR	CHERAS	BALAI POLIS SALAK SELATAN BARU	X	X	X	X	X	X	X
12	KUALA LUMPUR	CHERAS	BALAI POLIS SUNGAI BESI	X	X	X	X	X	X	X
13	KUALA LUMPUR	DANG WANGI	BALAI POLIS CHOW KIT	X	X	X	X	X	X	X
14	KUALA LUMPUR	DANG WANGI	BALAI POLIS DANG WANGI	X	X	X	X	X	X	X
15	KUALA LUMPUR	DANG WANGI	BALAI POLIS TUN H. S LEE	X	X	X	X	X	X	X
16	KUALA LUMPUR	SENTUL	BALAI POLIS JINJANG	X	X	X	X	X	X	X
17	KUALA LUMPUR	SENTUL	BALAI POLIS KEPONG	X	X	X	X	X	X	X
18	KUALA LUMPUR	SENTUL	BALAI POLIS SENTUL	X	X	X	X	X	X	X
19	KUALA LUMPUR	WANGSA MAJU	BALAI POLIS JALAN TUN RAZAK	X	X	X	X	X	X	X
20	KUALA LUMPUR	WANGSA MAJU	BALAI POLIS PUDU	X	X	X	X	X	X	X
21	KUALA LUMPUR	WANGSA MAJU	BALAI POLIS SETAPAK	X	X	X	X	X	X	X
22	KUALA LUMPUR	WANGSA MAJU	BALAI POLIS WANGSA MAJU	X	X	X	X	X	X	X
23	SELANGOR	AMPANG JAYA	BALAI POLIS AMPANG	X	X	X	X	X	X	X
24	SELANGOR	AMPANG JAYA	BALAI POLIS HULU KELANG	X	X	X	X	X	X	X

NO.	IPK	IPD	BALAI POLIS	2015	2016	2017	2018	2019	2020	2015-2020
25	SELANGOR	AMPANG JAYA	BALAI POLIS PANDAN INDAH	X	X	X	X	X	X	X
26	SELANGOR	AMPANG JAYA	BALAI POLIS TAMAN MELAWATI	X	X	X	X	X	X	X
27	SELANGOR	GOMBAK	BALAI POLIS DESA JAYA	X	X	X	X	X	X	X
28	SELANGOR	GOMBAK	BALAI POLIS GOMBAK	X	X	X	X	X	X	X
29	SELANGOR	GOMBAK	BALAI POLIS RAWANG		X	X	X	X		X
30	SELANGOR	GOMBAK	BALAI POLIS SELAYANG	X	X	X	X	X	X	X
31	SELANGOR	KAJANG	BALAI POLIS BATU 14	X	X	X	X	X	X	X
32	SELANGOR	KAJANG	BALAI POLIS BATU 18			X	X			
33	SELANGOR	KAJANG	BALAI POLIS BATU 9	X	X	X	X	X	X	X
34	SELANGOR	KAJANG	BALAI POLIS KAJANG	X		X	X	X	X	X
35	SELANGOR	PETALING JAYA	BALAI POLIS DAMANSARA	X	X	X	X	X	X	X
36	SELANGOR	PETALING JAYA	BALAI POLIS KELANA JAYA	X	X	X	X	X	X	X
37	SELANGOR	PETALING JAYA	BALAI POLIS KOTA DAMANSARA	X	X	X	X	X	X	X
38	SELANGOR	PETALING JAYA	BALAI POLIS LAPANGAN TERBANG SULTAN ABDUL AZIZ SHAH (LTSAAS)	X	X	X	X	X	X	X
39	SELANGOR	PETALING JAYA	BALAI POLIS PETALING JAYA	X	X	X	X	X	X	X
40	SELANGOR	PETALING JAYA	BALAI POLIS SEA PARK	X	X	X	X	X	X	X
41	SELANGOR	PETALING JAYA	BALAI POLIS SRI DAMANSARA	X	X	X	X	X	X	X
42	SELANGOR	PETALING JAYA	BALAI POLIS SUNGAI WAY	X	X	X	X	X	X	X

NO.	IPK	IPD	BALAI POLIS	2015	2016	2017	2018	2019	2020	2015-2020
43	SELANGOR	SEPANG	BALAI POLIS PUTRA PERDANA	X						
44	SELANGOR	SERDANG	BALAI POLIS SERI KEMBANGAN	X	X	X	X		X	X
45	SELANGOR	SERDANG	BALAI POLIS SERDANG	X	X	X	X	X	X	X
46	SELANGOR	SERDANG	BALAI POLIS PUCHONG	X	X	X	X	X	X	X
47	SELANGOR	SERDANG	BALAI POLIS BANDAR KINRARA	X	X	X	X	X	X	X
48	SELANGOR	SHAH ALAM	BALAI POLIS SEKSYEN 9		X		X			
49	SELANGOR	SUBANG JAYA	BALAI POLIS BANDAR SUNWAY	X	X	X	X	X	X	X
50	SELANGOR	SUBANG JAYA	BALAI POLIS SUBANG JAYA	X	X	X	X	X	X	X
51	SELANGOR	SUBANG JAYA	BALAI POLIS USJ 8	X	X	X	X	X	X	X
52	SELANGOR	SUNGAI BULOH	BALAI POLIS KAMPUNG BARU SUBANG	X	X	X	X	X	X	X
53	SELANGOR	SUNGAI BULOH	BALAI POLIS SUNGAI BULOH	X	X	X	X	X	X	X

Table 5: Z Score Hot Spot for the year 2015 until 2020

No.	Year	Z Score
1	2015	1.693747 - 4.812883
2	2016	1.722391 - 5.008024
3	2017	2.272012 - 5.713839
4	2018	2.563297 - 5.400317
5	2019	1.117944 - 4.527095
6	2020	1.481559 - 4.437961

data on violent crimes and the implementation of SDG-16, Getis-Ord Gi* statistics can help identify regions where violent crimes are concentrated and determine the impact of SDG-16 on reducing such crimes in Selangor, Kuala Lumpur and Putrajaya. By identifying areas with high concentrations of violent crimes and examining the geographical characteristics of crime hotspots, hotspot analysis using the Getis-Ord Gi* statistics can help with assessing the effectiveness of SDG-16 in achieving these goals. Employing the Getis-Ord Gi* statistic, researchers can examine whether the implementation of SDGs-16 has resulted in a decrease or an intensified concentration of violent crimes in certain locations. By comparing the local average of a variable (in this case, violent crimes) with the global average, the Getis-Ord Gi* statistic identifies geographic clustering.

In today's rapidly changing world, the significance of accurate Hot Spot Analysis

Statistics for addressing SDG-16: Community Policing and Violent Crimes cannot be overstated. Hot Spot Analysis Statistics, specifically the Getis-Ord Gi* statistic, plays a crucial role in helping community policing efforts to address violent crimes and contribute to the achievement of SDG-16 (Pehrson *et al.*, 2017; Ohta *et al*., 2022). The Getis-Ord Gi* statistics, a measure of spatial autocorrelation, helps identify clusters or hot spots of violent crimes within a given geographical area. Identifying and analysing these hot spots enables community policing agencies to prioritise efforts and effectively allocate resources strategically, focusing on areas with the most need implementing targeted interventions in spatial distributions with many violent crimes, ultimately leading to a reduction in crime rates and improve public safety within their communities (Chambers, 2019; Luo, 2017; Meng, 2017; Smith & Onésimo Sandoval, 2019; Zhu *et al.,* 2022). The Getis-Ord Gi* statistic is widely used in crime analysis and mapping because it provides z scores that can determine confidence thresholds and assess the statistical significance of hot and cold spot locations (Käthner *et al*., 2017; Zhou *et al.,* 2021). With the help of Getis-Ord Gi* analysis, community policing agencies can identify areas with a high concentration of violent crimes, known as hot spots, where the occurrence of violent crime is significantly higher than expected based on random chance. In conclusion, the identification of spatial clusters of violent crimes episodes using the Getis-Ord Gi* statistic and z-score facilitates the analysis of SDG-16. SDG-16 contributes to reducing violent crimes and promoting safer and more inclusive societies by promoting peace, justice, and strong institutions.

Significant clusters have been found by carefully examining violent crime statistics from multiple places; these clusters are denoted by elevated Z-scores (Table 6). High Z scores were notably recorded in 2015 within the Pantai Police Station Boundary (PSB), peaking at Jalan Tun Razak PSB in 2016. At Ampang PSB, this pattern persisted in 2017, and rising Z-scores persisted until 2020. The persistent nature and relevance of these hotspots are highlighted by these findings, which have been consistent over a period of six years and mostly locate inside the Kuala Lumpur Contingent Police Headquarters (KLCPH) and numerous places of the Selangor Contingent Police Headquarters (SCPH). The ongoing discovery of hotspots close to police headquarters raises the possibility of underlying relationships between changes in the population, advancements in urban infrastructure, or socioeconomic variables that need more research. In order to effectively reduce crime rates and improve public safety, this analysis gives law enforcement agencies and policymakers vital insights that allow for the strategic deployment of resources towards areas with heightened criminal activity.

The Z-scores' revelation of hotspots highlights the significance of a data-driven strategy in crime prevention and law enforcement tactics. Authorities can maximise the impact of their efforts and raise the general efficacy of crime reduction programmes by focusing interventions on areas with notable concentrations of crime by using spatial analytic tools. Furthermore, pinpointing regions with continuously low Z-scores offers a chance for proactive crime prevention and focused community policing, underscoring the possibility of deliberate interventions in lower-risk areas. Critical hotspots and locations with lower crime concentration are identified by the Hot Spot Analysis Statistic (Getis-Ord Gi*) by Location, which offers insightful information about the spatial distribution of property crime. By helping law enforcement prioritise efforts and resources, this research ensures a focused approach to improving public safety and preventing crime. Going forward, in order to address shifting trends and new threats and build safer, more secure communities, it will be crucial to continuously monitor and analyse crime data in order to modify and evolve plans.

GIS serves as a multifaceted tool for community policing, offering capabilities that range from data analysis to spatial mapping and community engagement. Akpan *et al.,* (2018) outline how GIS can assist police officers in

Table 6: The Highest Z Score Hot Spot from the year 2015 until 2020

2015							
No.	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**GiZScore**	**GiPValue**	**Gi_Bin**	**Significant Level**
1.	Kuala Lumpur	Wangsa Maju	Jalan Tun Razak	4.812882976	1.48768e-06	3	99%
2.	Kuala Lumpur	Dang Wangi	Tun H. S. Lee	4.763014932	1.90722e-06	3	99%
3.	Selangor	Dang Wangi	Jalan Dang Wangi	4.721135576	2.34532E-06	3	99%
4.	Selangor	Sungai Buloh	Kampung Baru Subang	2.24154735	0.024990642	2	95%
5.	Selangor	Subang Jaya	USJ 8	1.963541043	0.04958334	2	95%
6.	Selangor	Kajang	Kajang	1.829371302	0.067344004	1	90%
2016							
No	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**GiZScore**	**GiPValue**	**Gi_Bin**	**Significant Level**
1.	Kuala Lumpur	Wangsa Maju	Jalan Tun Razak	5.008024	5.5e-07	3	99%
2.	Kuala Lumpur	Dang Wangi	Jalan Dang Wangi	4.926845	8.36e-07	3	99%
3.	Kuala Lumpur	Dang Wangi	Chow Kit	4.862293	1.16e-06	3	99%
4.	Selangor	Serdang	Serdang	2.200648	0.027761	2	95%
5.	Selangor	Serdang	Seri Kembangan	2.014795	0.043926	2	95%
6.	Selangor	Gombak	Rawang	1.933309	0.053198	1	90%

2017							
No	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**Gizscore**	**Gipvalue**	**Gi_Bin**	**Significant Level**
1.	Selangor	Ampang Jaya	Ampang	5.710655	1.12542e-08	3	99%
2.	Kuala Lumpur	Wangsa Maju	Jalan Tun Razak	5.68508	1.30751e-08	3	99%
3.	Selangor	Ampang Jaya	Hulu Kelang	5.660711	1.50747e-08	3	99%
4.	Selangor	Serdang	Seri Kembangan	2.799789	0.005113599	2	95%
5.	Selangor	Subang Jaya	Subang Jaya	2.702819	0.006875415	2	95%
6.	Selangor	Subang Jaya	USJ 8	2.276653	0.022806977	2	95%
2018							
No	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**GiZScore**	**GiPValue**	**Gi_Bin**	**Significant Level**
1.	Selangor	Ampang Jaya	Ampang	5.400316919	6.65233e-08	3	99%
2.	Kuala Lumpur	Dang Wangi	Jalan Dang Wangi	5.390848149	7.01259e-08	3	99%
3.	Kuala Lumpur	Dang Wangi	Tun H. S. Lee	5.380129605	7.44322e-08	3	99%
4.	Selangor	Gombak	Rawang	1.893532	0.058287	1	90%
5.	Selangor	Shah Alam	Seksyen 9	1.841639	0.065528	1	90%
6.	Selangor	Kajang	Batu 18	1.728231	0.083947	1	90%
2019							
No	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**GiZScore**	**GiPValue**	**Gi_Bin**	**Significant Level**
1.	Selangor	Ampang Jaya	Ampang	4.527095	5.98E-06	3	99%
2.	Kuala Lumpur	Wangsa Maju	Jalan Tun Razak	4.325867	1.52E-05	3	99%

3.	Selangor	Ampang Jaya	Hulu Kelang	4.282953	1.84E-05	3	99%
4.	Selangor	Subang Jaya	USJ 8	2.004863	0.044978	2	95%
5.	Selangor	Serdang	Serdang	1.907843	0.056411	1	90%
6.	Selangor	Gombak	Rawang	1.693207	0.090416	1	90%
2020							
No	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**GiZScore**	**GiPValue**	**Gi_Bin**	**Significant Level**
1.	Selangor	Ampang Jaya	Ampang	4.437961	9.08E-06	3	99%
2.	Kuala Lumpur	Dang Wangi	Tun H. S. Lee	4.335196	1.46E-05	3	99%
3.	Kuala Lumpur	Wangsa Maju	Jalan Tun Razak	4.333436	1.47E-05	3	99%
4.	Selangor	Serdang	Serdang	1.974228	0.048356	2	95%
5.	Selangor	Kajang	Kajang	1.970853	0.048741	2	95%
6.	Selangor	Serdang	Seri Kembangan	1.77967	0.07513	1	90%
2015-2020							
No	**Contingent Police Headquarters (CPH)**	**District Police Headquarters (DPH)**	**Police Station (PS)**	**GiZScore**	**GiPValue**	**Gi_Bin**	**Significant Level**
1.	Kuala Lumpur	Wangsa Maju	Jalan Tun Razak	5.309043	1.1E-07	3	99%
2.	Selangor	Ampang Jaya	Ampang	5.211868	1.87E-07	3	99%
3.	Kuala Lumpur	Dang Wangi	Jalan Dang Wangi	5.206949	1.92E-07	3	99%
4.	Selangor	Serdang	Seri Kembangan	2.361335	0.018209	2	95%
5.	Selangor	Subang Jaya	USJ 8	2.349145	0.018817	2	95%
6.	Selangor	Kajang	Kajang	2.273779	0.022979	2	95%

analysing problems through comprehensive, up-to-date data, consequently enabling the identification of crime patterns. It aids in the intelligent deployment of officers by pinpointing crime hotspots and analysing spatial relationships, thus freeing up more officers for proactive, problem-solving tasks. Additionally, GIS empowers communities by involving the public in policymaking, serving as a medium to achieve the objectives of community organisations. Also, Schwartz & Boboricken, (1999) delve into the development of the Crime Analysis Program and Event Reporting System (CAPERS) in Jefferson County, Colorado. This system enhances traditional data analysis methods by adding a spatial component to criminal activity. CAPERS allow officers to conduct queries, generate graphical and tabular reports, and analyse events by precincts and beats. As law enforcement professionals in the County become more adept at using geographic data, the system is expected to incorporate advanced features like linear spline regressions, spatial-temporal cluster analysis, and predictive modelling tools for the crime. Overall, it emphasises how GIS can significantly benefit decision-making and policy formulation in community policing.

Implications, Limitations, Suggestions for Future Research and Recommendations

The implications of this study extend to various stakeholders, including law enforcement agencies, policymakers, local authorities, and the broader community (Falls & Thompson, 2014; Humphreys & Soebbing, 2014; Bottan *et al.,* 2017). By demonstrating the potential of GIS in identifying crime hotspots and analysing spatial crime patterns, the study aims to contribute to data-driven crime prevention strategies. Specifically, it can assist authorities in optimising resource allocation, enhancing community safety, and ultimately promoting peace, justice, and strong institutions, aligning with the objectives of SDG-16. Furthermore, the exploration of collaboration opportunities with private corporations like Google and Alibaba underscores the potential for leveraging external support to overcome challenges in data collection and technology adoption, thereby facilitating sustainable development.

The study acknowledges several limitations, including funding disruptions due to the COVID-19 pandemic, policy changes, difficulty in accessing geospatial data, and limited financial resources for data collection (Dai *et al.,* 2001; Sia *et al.,* 2021). To address these limitations and guide future research, specific suggestions are provided. Firstly, there is a need for more comprehensive and targeted data collection efforts, especially in developing countries, to support effective GIS analysis. Additionally, future research can focus on exploring the impact of urban planning aspects such as walkability and access to green spaces on crime rates, thereby contributing to a deeper understanding of the relationship between crime, time, and land use. Moreover, articles focusing on the integration of GIS with SDG-16 in developing countries can provide valuable insights for future studies to build upon and address the identified research gap effectively (Boitani *et al.,* 2011; Hodza *et al.,* 2023).

Future research can benefit from examining articles that delve into the integration of GIS with SDG-16, particularly in the context of developing countries. Studies that explore the effectiveness of GIS in addressing crime patterns, optimising resource allocation, and promoting community safety can provide valuable insights for advancing research in this area. Additionally, articles focusing on the challenges and opportunities of collaboration with private corporations to support SDG implementation in developing countries can offer relevant perspectives for future investigations. By building upon existing literature and addressing the identified research gap, future studies can contribute to enhancing our understanding of the role of GIS in achieving SDG-16 and promoting sustainable development globally (Caiado *et al.,* 2018; Im, 2020; Ishtiaque *et al.,* 2020; Yuan, 2021).

Conclusions

This article underscores the pivotal role that GIS can play in advancing SDG-16, which focuses on security, justice, and strong institutions. GIS serves as a powerful tool for identifying areas requiring intervention and assisting in precise planning and policymaking. The technology is particularly beneficial for local authorities in formulating strategies to uphold public peace and law enforcement. Recognising the connection between land use and crime opens the door for more effective, targeted interventions, leading to safer communities. Looking ahead, future research can delve deeper into the relationship between crime, time, and land use, examining how urban planning aspects like walkability and access to green spaces influence crime rates and contribute to sustainable development.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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