Combining the richness of GIS techniques with visualisation tools to better understand the spatial distribution of data – a case study of Chicago City crime analysis

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Abstract: This study aims to: 1) to explore the benefits of adding a spatial GIS layer of analysis to other existing visualisation techniques; 2) to identify and evaluate the patterns in selected crime data by analysing Chicago's open dataset; 3) provide a better understanding of patterns and prediction of crime trends within the selected geographical location. We conclude that Chicago seems to be on course to have both the lowest violent crime rate since 1972, and the lowest murder frequency since 1967. Chicago has witnessed a vigorous drop in most crimes types over the last few years in compares to the previous crime index data. Also, Chicago crime naturally upsurges during summer months and declines during winter months. Our study results align with previous several decades of studies and analysis of Chicago crimes, in which the same communities of highest crime rates still experience the mainstream of crime.

Keywords: spatial distribution; geographic information system; GIS; crime analysis; visualisation tools; GIS techniques; data visualisation; crime mapping.

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1 Introduction

The internet has briskly advanced in the 21st century to more than just a tool for communication. The internet has profoundly influenced and significantly embedded itself into the political, social and cultural fabric of our daily lives on a local and global scale. Consequently, this has dramatically modified the nature of the crime, how we analyse and understand it, and more importantly, the responses for crime control (Boba, 2016). These technological advancements have enhanced crime analysis and enable the practitioner to draw more meaningful insights. Simultaneously, criminological research has shared similar viewpoints – that crime is spatially focused – because of which, experts can bring a better understanding of the spatiotemporal distribution of crime data.

In the same vein, Brunsdon et al. (2007) discussed that police efforts move towards producing what is branded as 'crime hotspots' within these concentrated areas. Geolocation-based analysis has proved to be useful in mitigating and tracking crime. Likewise, researchers have started realising the significance of combining the spatial and temporal components of crime data. These grounded research outcomes are favoured by police and crime prevention departments regarding arming them with better insights to direct police activities within various spaces and time scales. Authors utilised spatiotemporal analysis to understand how robbery events could be forecasted at "significantly elevated rates of burglary within 1–2 months temporal band and within a range of up to 300–400 meters spatial band of a burgled home" (250) in Merseyside County in the UK. These pragmatic discoveries of recurrence and near-recurrence robbery patterns offer talented theoretical crime detection.

Another example of the usefulness of using spatiotemporal patterns of crime hotspots is Nakaya and Yano (2010). The authors explore the potential of using 3D crime maps by combining the space-time cube approach and modifications of kernel density approximation and scan statistics. The combination of these two approaches reveals temporal inter-cluster correlations that suggest a new type of 'displacement phenomenon' of crime. The combining of these approaches is predominantly valued for a spatiotemporal investigative data analysis of clusters to abstract new facts of crime epidemiology from a space-time crime data.

The field of spatial crime epidemiology analysis has evolved rapidly in the past two decades. In Haining (2003), the study shows that the mapping and spatial investigation of crime encompasses a spread-out scope of methods and has been utilised to investigate an assortment of themes. Crime mapping can be used to envisage and explore the development pattern of crimes. Crime mapping uses geographic information system (GIS) to forecast and visualise spatial information for more formal factual examination. The spatial investigation can be used in both an exploratory and a more corroborative way, given the primary

Role of recognising how specific groups or built environment characteristics impact the spatial distribution of crime. Mapping tools offer the creation of pin maps, and by spatially sorting out the crime data, GIS expands the explanatory power of these maps to enable experts to explore crime patterns, offender mobility, and serial offences concerning time and space.

Aragon et al. (2016) showed that nowadays, there is a growing flow of interest in data visualisation, its capability to communicate new insights effectively, and the proliferation of techniques for producing various visualisations. These quantitative methods could be supported by adding another layer of analysis using multiple qualitative methods and cues to provide a more meaningful interpretation of the analysed data. The focus on human-centred data techniques best describes the combination of both approaches. Even though data visualisation tools offer a richer understanding of several applications, the extracted insights may lack the qualitative interpretations various socio-technical concerning phenomena.

1.1 Problem statement

This paper, studies, analyses, and attempts to answer the following research questions:

- 1 To what extent we can support the use of existing, powerful visualisation tools in combination with the use of GIS spatial analysis tools to understand the crime description and trends within Chicago City?
- 2 What are the benefits, challenges, implications of this combination?

Our argument built on the premise which Aragon et al. (2016) pointed out that there is a real need to apply a human-centred data science approach to data analysis and visualisation. This approach is born as a joint effort of human-computer interaction, cooperative work between human computation and computer support, and the statistical and computational tools of data science (Luczak-Roesch et al., 2015; Lin et al., 2009). As such, this paper explores the potential of using both GIS and visualisation tools to understand the crime data within Chicago City better. Also, we sought to offer recommendations for the best crime data analysis practices and to highlight some existing research gaps for future investigation.

- 1.2 Study objectives
- 1 Map crime incidents around Chicago City for the period 2001–2018.
- 2 Identify crime hot spots and other patterns to help in maximising the effectiveness of police resources and maximise efficiency.
- 3 Identify locations and neighbourhoods where significant crimes occur (sexual assault, rape) and the incidents of criminal activity are high to direct police patrols and presence in those affected areas.
- 4 Overlaying additional layers of socio-economic and demographic data permits for the formulation of more cost-effective and contextual crime reduction strategies through the appropriate deployment of resources based on mapped and analysed incidents of crime in Chicago City.

1.3 Study contribution

The fruitful application of our study approach results in a better understanding of an enormous number of social issues that are being examined and analysed by data scientists. Additionally, the social phenomena associated with a crime cannot be understood fully without the consideration of human factors that may assist in addressing the challenges of drawing meaningful insights from visualisation tools. As such, we attempt to:

- 1 use selected visualisation tools and GIS spatial analysis to represent the crime rate trends based on a Chicago City crime open dataset
- 2 explore the benefits of utilising a human-centred database approach by investigating the relationships between the spatial distribution of crime and

neighbourhood characteristics using the GIS spatial approach.

Then, we will evaluate the benefits and challenges of using such a holistic approach and draw a succinct recommendation and further guidelines for applying such an approach. Also, this is just an example to explore in this short timeline. In the long-term, one can examine the visualisation and exploration techniques for various Big Data types to underpin several socio-economic issues.

Similarly, other studies focused on using big data analytics for automatic event detection in smart cities, which can be applied in crime analysis context as well. In Suma et al. (2018), the authors use big data and machine learning platforms including Spark, and Tableau, to analyse Twitter data about London. Concurrently, they utilised the Google Maps Geocoding API to detect the tweeters and perform additional analysis. They analyse over three million tweets (their locations and times) to detect the occurrence of multiple events, including the London Notting Hill Carnival 2017 event, the analysis performed without any previous knowledge of the event. Authors identify congestion issues around London and determine that events can be detected automatically by analysing data.

1.4 Paper structure

This study consists of a literature review, data analysis using various tools [ArcMap (Esri, 2018) and Tableau (Tableau Software Inc, 2019)] and a proposed research design that is intended to augment our understanding and add more insights to crime data analysis. We execute this task through an in-depth multi-disciplinary analysis that covers a broad spectrum of disciplines ranging from psychology to human-computer interactions, to geographic spatial location analysis to statistics and many disciplines in between. These different disciplines ultimately reflect the complexity of crime data analysis. We use thematic analysis to discuss the reviewed literature, followed by a thorough comparative gap analysis. We propose a multi-dimensional crime data analysis that addresses some of the pressing issues mentioned in the gap analysis. Furthermore, we cross-examine our analysis approach to previously existing examples in literature. We conclude by analysing some of the limitations of our approach and some of the barriers that it may overcome.

2 Background

We divide the background into five subsections to cover various aspects of crime data analysis. In these sections, we analyse works related to the relationship between crime analysis and various methodological and technological aspects; we review other existing examples of crime analysis; we identified the significant gaps in the reviewed literature. Lastly, we discussed the comparative gap analysis and current study focus.

2.1 GIS and crime data analysis

Geographic information system (GIS) plays a pivotal role in enhancing our understanding of crime mapping analysis. The GIS allows for the connecting, processing, and analysis of crime mapping information quickly. In Shafique et al. (2017), the authors explain that although GIS offers the ability to connect and process information rapidly, the presentation of the processed results is provided in an appealing spatial and visual way that enables users and agencies to allocate required resources quickly and more efficaciously is lacking.

Nakaya and Yano (2010) explore the potential of using 3D models to map crime incidents in a space-time cube with the support of space-time variants of kernel density estimation and scan statistics. Authors utilised the crime occurrence dataset of 'snatch and ran' offences in Kyoto City. Their proposed methodology offers synchronised visualisation of the duration of crime clusters and its geographical extent. They suggest that mingling these methods in a space-time cube presentation is predominantly valued for a spatiotemporal experimental data analysis of clusters that can be used to derive new insights of crime epidemiology using a dataset of space-time crime incidents.

Another example shown in Brunsdon et al. (2007) explored the space-time crime patterns by comparing the effectiveness of the static map with interactive dynamic visualisation methods. Their focus was precisely on the role of animation in the interpretation of crime patterns and comprehending the primary factors that impact such forms. Their work is valuable regarding enriching the discussion and knowledge of the effectiveness of a broad spectrum of visualisation tools used to understand spatiotemporal crime trends. They evaluate the capability of three visualisation tools (map animation, the isosurface, and the co-map) in the examination of distribution patterns in space-time crime data. They suggested that further research is warranted to implement these techniques to other crime data sources such as health. Where recommended study may offer a holistic understanding of the opportunities and challenges of these visualisation exploration tools.

Another study (Shafique et al., 2017) about the role of GIS in crime mapping and analysis, their paper explores the various functionalities and use of GIS in identifying and representing the crime hotspots and its importance in enhancing the police investigation inclination strategy. They reviewed and synthesised numerous papers and summarised diverse methods that aid authors to comprehend spatial analysis of crime and to expand their argument on the noteworthy role GIS has in crime analysis. They conclude that the GIS functional approach in crime mapping investigation could be fruitfully used to improve the 'user interface stage', which contributes to the improvement of the safe city strategy.

GIS has been used in serial crime analysis via data mining techniques (including for serial crimes committed by marginal offenders). The police investigators considered this problem to be a complex task, as it requires the investigation of a massive number of crimes which are unconnected from each other. Thus, serial crime needs to be analysed in a specific way to figure out the existing connections between each crime that have occurred in different locations. In Sivaranjani et al. (2016), the authors critiqued the previous use of the cut clustering algorithm (CCA) to cluster serial crime. The CCA lacks the number of labelled classes used for clustering due to limited use of data points, and the CCA used in the previous research was more complicated due to a lack of subgraph characteristic specification creation. As such, the authors attempted to resolve these problems by using the 'weighted majority minority oversampling' technique to lever the class unevenness problem. They also introduced dynamic cut clustering to overcome the restrictions of the graphic cut clustering algorithm. They utilised the quantum geographic information system (QGIS) tool to visualise, navigate, manipulate, and analyse selected geographic crime datasets.

Another study of crime place analysis (Deryol et al., 2016) used GIS combined with other statistical tools so that the authors could offer an illustration of a statistical test of the Brantinghams' theory about the creation of hotspots and the effects that nodes, paths, and environmental topography have on their expansion. They used multi-level Poisson regression analysis to explicate discrepancy in the number of occurrences at each address. They measured place-level proximity to nodes and paths using GIS by applying the Euclidian distance in each location to the nearby drinking businesses and bus routes. The tripartite interaction concerning the distance to the nearby on-site liquor store. The distance to closest liquor facility, and the distance to the nearby bus route, which was significantly and negatively related to place-level crime occurrences. This three-way interaction method (which varied across neighbourhood contexts) had stronger adverse effects on crime happening in neighbourhoods characterised by the high-density commercial establishments. This study was critical in terms of supporting the notion of a multilevel philosophy of crime places and has influenced more efficiently controlling crime. Multiple nodes and paths within a proximal surrounding and commercial land density within border areas are likely to need further crime prevention measures.

Kester (2013) argues that there are many challenges encountered when people work in crime analysis. Difficulties arise in the graphical visualisation of crime data patterns. Most importantly, in these visualisations is showing the crime type and the geographical representation of crimes in a location. These features offer a practical and accessible means of monitoring unlawful activities and analysing them to suggest effective antidotes and precautionary procedures in resolving these criminal activities. Thus, their paper proposes a novel method of scrutinising and visualising crime patterns of geographical crime data through the use of formal concepts analysis (FCA) or Galois lattices (a data analysis method grounded on Lattice theory and propositional Calculus). This technique measured the set of standard and discrete characteristics of crimes in such a way that classification has completed the build on related crime types. The advantages of this method are to build a more distinct and theoretical system for analysing geographical crime pattern. So, these computer systems will have the capability to offer insights from data and to create a visual diagram of crime data to solve, understand and analyse crime patterns directly.

2.2 Crime reporting

Crime reporting practices have a tremendous amount of literature as reporting is significantly correlated with law enforcement efforts to control crimes and provide them with the excellent opportunity to prevent criminal activities. Law enforcement crime measurements are formed and could be improved by victims' decisions to report crime incidents. In this section, we summarise some selected examples related to crime reporting.

In Estienne and Morabito (2016), the authors investigated differences in crime reporting practices by applying a comparative approach. They evaluated the generalisability of associates of burglary and mugging reports to the police in a non-US sample to identify if there are national variances in crime reporting practices. Their paper developed an expanded model that integrated crime incidents, demographics, police-related issues, and various nationwide variables. This model proposed to enhance police and planners understanding of variances in reporting practices within developing and developed nations. Their findings acknowledged crime reporting practice similarities and differences among developed and developing countries. They concluded by confirming the vital role of the incident and demographic features on reporting a crime, and they recommended to include nationwide variables that reflect the economic and social context in any scholarships that investigate reporting practices.

In the same vein, another study (Xie, 2014) uses the US National Crime Victimization Survey to scrutinise spatial variances and temporal tendencies in crime reporting in New York and other metropolitan areas between 1979 and 2004. They found that the net crime characteristics and survey methodology showed that the New York City had scarcer upsurges in crime reporting compared to other cities. These differing trends propose that the real variances in the drop of violence between New York and other cities may have been slighter than those specified by police-based crime statistics. Additionally, the study revealed that between 1990 and 2004, New York showed a steep decline in the probability that victims thought that 'police would not help'; thus, they suggest that scholars need to advance a broader theoretical framework to comprehend how police and non-police-related aspects may clarify the geographic difference in crime reporting that was observed in their study.

2.3 Chicago crime analysis

In a very current study about the relationship between gun theft and crime, Cook (2018) analysed freely accessible national data about gun theft in Chicago City. The paper synthesised the most significant existing evidence on the number of yearly stolen guns and where these stolen guns were used in committed crimes within Chicago City. Their findings suggest that stolen guns have a minimal role in crimes for three rational reasons:

- 1 open source data was used to calculate that thefts are only responsible for one percent of all gun transactions in national level
- 2 the analysis of the Chicago original crime data validated that less than three percent of guns retrieved by the Chicago Police Department had been filed as stolen occurrences
- 3 survey findings of condemned offenders recommend that it be infrequent for accused to have stolen the gun used in a most recent crime.

They concluded with a detailed and in-depth recommendation for future research agenda aimed towards researching the certainty of the role of gun theft in crime. The data on which these findings are based have various shortcomings. A research agenda was proposed that would provide more certainty about the role of theft. Their examination revealed pertinent issues methodically, rather than depending on presumption (Cook, 2018).

In a recent analysis on the spatial variability of violent crime in Chicago, a study Schnell et al. (2017) examines the impact of community areas, street segments and neighbourhood clusters on crime variability violence in Chicago. They discussed the implications of three hierarchical units of analysis on the total spatial variability of violent crime occurrences in Chicago. They analysed violent crime occurrences reported to police authorities from 2001 to 2014. As such, they geocoded 359,786 crime occurrences to 41,926 street segments which are located within 342 neighbourhood areas within 76 municipals areas in Chicago. By using linear mixed models with the estimation of the random slopes of time, they detected the variance individually ascribed to each unit of analysis. They found that 56 to 65% of the entire variability in violent crime occurrences can be attributed to street segments in Chicago. Their results suggest that researchers interested in understanding the spatial variation of crime across urban landscapes should be looking at the smaller locations that encompass larger geographic areas.

2.4 Crime interpretation and forecasting

Crime analysis is a diverse and complex field, and knowledge is needed in many different domains (Walker and Drawve, 2018). Crime interpretation and prediction requires permit law enforcement agencies to achieve their work more efficiently and proactively within a short time using limited resources. Police department databases embrace a massive volume of crime data that could be utilised to enlighten us about existing and upcoming crime pattern trends. In Schnell et al. (2017), the authors explain that the objective of crime interpretation and forecasting is to advance our understanding of crime trends to construct efficient strategies that will mitigate and prevent crime. Thus, predictive analysis is of ongoing social awareness based on the understanding and deterrence of crime, to improve the use of crime data to antedate criminal actions.

In Rummens et al. (2017), the authors built and tested a model that makes use of predictive analytics in spatiotemporal crime forecasting within an urban context. They examined the available crime data for three types of crime, including home robbery, street burglary, and battery, then they aggregated them spatially to grids of 200 by 200 metres and analysed them in retrospect. They applied a collaborative model and synthesised the results of logistic regression and neural network model, which lead to fortnightly predictions for the year of 2014, dependent on the previous three years of aggregated crime data. They also made a monthly forecast of a day versus night prediction of crime occurrences. These predictions were made based on few criteria: straight hit rate; the precision of accurate estimates as opposed to the total number of projections; and the prediction index which refers to the ratio of direct hit rate versus the proportion of the whole zone predicted as high risk. They concluded that it has the potential to achieve realistic predictions by carrying out a predictive analysis at the grid-level of crime data. More notably, monthly forecasts with a variance between day and night generated better results compared to the bi-weekly projections.

Similarly, in Pecharromán (2016), the author used geo-intelligence to investigate predictive crime analysis. The author presented a new technique for crime predictive analysis using geospatial analysis and geo-intelligence methods via GIS. This technique can assist in preventing crime by foreseeing the place and time of impending crime before it takes place; in doing so, the police can adjust resources accordingly. His analysis was based on a dataset in San Francisco, where he applied two types of analytical techniques:

- retrospective analysis comprising of hotspot analysis, time-based analysis, space-time analysis, and proximity repetition models (models that predict future crime based on investigating the location of crimes previously committed
- 2 prospective study the recognition of the geographical indicators that may combine in a particular way to contribute to an increase in the risk of crime in a specific area, used to predict the likelihood of future crime.

The auditor recommends combining both methods to obtain more meaningful results.

2.5 Data visualisation and crime trends understanding

In Stamatel (2015), the author discusses how data visualisation can improve analytical thinking in cross-national crime research. Cross-national criminology research is logically rooted in spatial and historical contexts. Nevertheless, cross-national crime scholars hardly employ data visualisation methods to illustrate associations between crime, time, and space. Thus, the author claims that using data visualisation methods can enable data analysis, causal reasoning, and theoretical development or cross-national criminology. As such, the paper re-evaluated homicide data rates in 34 nations from 1956 to 1998. This cross-national re-analysis validated the value of data visualisation techniques within the cross-national criminology context. To do so, the author employs two visualisation methods: mapping and sparklines. This technique is based on the argument that how we perceive the data impacts how we think about data. They concluded that the illustration of data demonstrates new patterns that were not otherwise attainable from the original analysis; thus, inspiring deep theoretical and conceptual thinking of crime trends. In other words, mapping the data helps to illustrate spatial relations and to produce sparklines to determine temporal associations. This paper revealed that these simple data visualisation techniques can permanently influence analytical perspectives and leads scholars to think distinctively about the data in contrast to what conventional analysis can offer. As such, the paper confirmed that data visualisation techniques provide further mechanisms for cross-national crime scientists to better integrate space and time crime variables in their crime analyses.

In Graham and Mehmood (2014), the authors explore the crime-sourcing approach as a newly emerging method in fighting against criminal activities. They introduce what called the strategic prototype of what they called 'crime-sourcing' and the science fiction behind it. The study employs a science fiction prototyping (SFP) and crowdsourcing, which considered being capable method that able to encapsulate all domains of the human landscape such as science, social or business. Authors used SEP methodology to realise innovative crowdsourcing notions. They offer a fictional scenario that hypothesises how crowdsourcing possibly will be combined with emerging technology to advance what they called а 'crime-to-conviction' model. The emphasis of their prototype, 'Crime-sourcing' is Murder Hunt - which is crowdsourcing site that seeks to offer vibrant information about murders and the means necessary to track, report to authorities which then take appropriate action of capturing the killer. It is a stimulated prototype based upon evidence to discover novel, innovative tools. The authors also, acknowledged the high potentials that they would not have realised if they had not offered them in a fictional mode. The paper contributes to better understand the crowdsourcing theory and the challenges that must be overcome if proposed SEP prototyping is to be an established foresight methodology.

A recent study (Butkovic et al., 2019) scrutinises cybercrime profiling techniques that ubiquitous nowadays, and emphases on the viability of deploying geographic profiling method to cybercrime issues that involve a physical world, with particular focus on two types of cybercrimes that are credit card skimming and spear phishing (is a specific type of attack that focuses on a specific individual within an organisation). Thus, authors perform testing the utility of geographical profiling on real cybercrime examples offered by law enforcement agencies. Then, they implemented a GeoCrime- geographic profiling software intended to support in the mapping, spatial and statistical analysis of cybercrime patterns. The study has revealed that applying geographic profiling to certain types of cybercrimes and under certain conditions has great potential. Particularly in the in circumstances where is lack of information about the offender, such as in cybercrime, as offenders usually use the internet to hide their identities and activities.

2.6 Gap analysis

After our selected literature review of GIS crime mapping and other visualisisation literature that is designed to assist in improving crime data analysis, we are still left with several gaps. Despite the efforts of the ongoing research in mapping and visualisation crime data, we believe further work is warranted. Throughout this review, we have identified several gaps in the literature. Some of the overarching problems that endure are the lack of comprehensive crime analysis that focused on the built environment characteristics and how it could be used to inspire and add additional interpretation and insights into crime analysis. Following is a list of some of the most critical problems and gaps we have come across in the literature:

- There is a growing need for the different state and federal law enforcement agencies to identify and act against hotspots crime as well as fundamental environmental and socio-economic characteristics connected with that crime originator (s).
- There is a considerable gap in crime mapping between practice and theory. Theory and practice are different, as most institutes teach crime mapping theoretically and there is a lack of practical experiences to develop maps using the GIS and other spatial and visualisation. Also, the literature on crime mapping and analysis is scattered and challenging.
- There is a need for a holistic crime analysis solution that integrates qualitative and quantitative tools to improve our understanding of crime date, and this gap aligned with the argument of the significance of combining of both approaches is best described by the focus on human-centred data techniques (Aragon et al., 2016).

• Another area of consideration is the need to analyse crime data into different scales from national to local (micro) and, neighbourhood, block to block for all crime analysis. Several studies examined both temporal and spatial variation in crime in a larger and smaller

scale, but still, there is a need to perform analysis across street blocks in the chosen area of investigation.

We conducted a comparative analysis of the reviewed literature, as illustrated in Table 1.

Table 1Comparative analysis

| Reference | Topic | Problem statement | Theoretical contribution | Methodology |
|------------------------------|---|--|---|---|
| Graham and Mehmood (2014) | 'Crime-sourcing and the science fiction behind it | Explore the SFP and crowdsourcing methodologies and presents 'crime-sourcing'. | Crowdsourced theory | Science fiction prototyping (SFP) |
| Butkovic et al. (2019) | Geographic profiling for serial cybercrime inquiry | Apply the concept of geographic profiling to the issue of cybercrime that involves a physical world, targeting two types of cybercrimes: credit card skimming and spear phishing. | Expand the discussion in the mapping, spatial and statistical analysis of cybercrime patterns | Testing the utility of geographical profiling on real cybercrime samples |
| Boba (2016) | The growing field of crime analysis. | The book covers three analysis categories: strategic analysis, tactical analysis and administrative crime analysis. | Offer a comprehensive analysis | Intelligence and criminal investigative analysis are also discussed |
| Brunsdon et al. (2007) | Visualising space and time in crime patterns | Expand the discussion to include the usefulness of a broader range of visualisation techniques. | Broaden the discussion of the effectiveness of visualisation techniques of spatiotemporal crime trends | Using three visualisation techniques, which are the map animation, the comap and the isosurface) |
| Nakaya and Yano (2010) | Visualising crime clusters in a space-time cube | They investigate the prospect of 3Ds mapping of criminal actions in a space- time cube. | They used space-time variants of kernel density estimation and scan statistics | Space-time visualisisation technique. Space-time kernel density estimation |
| Walker and Drawve (2018) | Practicalities of crime analysis | This chapter introduces the practicalities of the work life of a crime analyst | Contribute to the foundations of crime analysis | Interviews with crime analysts. |
| Baraka and Murimi (2019) | Challenges of transition from manual to computerised crime mapping | identify challenges to the adoption of computerised tools such as geographical information systems (GIS) | They offer a comprehensive qualitative approach in their analysis | Interviews and focus group discussion Use of the technology acceptance model (TAM) |
| Aragon et al. (2016) | Developing a research agenda for human-centred data science | Preserving the richness associated with traditional qualitative methods whereas using the power of large datasets Find ways to uncover social nuances or consider ethics and values in data use | Their argument stems from the fact that computational approaches provide researchers access to extensive collections of data. | Using human-centred data science. Discussion over multi- institute and interdisciplinary collaboration. |
| Lin et al. (2009) | Challenges in human-centred information visualisation | Authors interrogate the connection between information visualisation and human cognitive loads. | Introduction to the Special Issue to expand the discussion to bridging the existing gaps between the various disciplines | They developed model in uncovering the relationship between visual understanding and domain complexity, data complexity, task complexity and visual complexity. |
| Shafique et al. (2017) | GIS importance in crime mapping analysis | Utilises various capabilities of GIS to identify the crime hotspots. | Encourage the advancement of investigation inclination strategy for policing GIS applications | Blends statistical methods (cluster analysis) and spatia models created with GIS, established on police crime reports. |
| Sivaranjani et al. (2016) | GIS-based serial crime analysis viz using data mining techniques | Investigate different ways to discover the serial crimes, one needs to examine a large number of crimes which are unlinked with each other | The serial crimes have been clustered by using dynamic cut clustering algorithm efficiently | Graph-based clustering algorithm to cluster the input database They used QGIS open source platform to evaluate and map the series of crime locations. |

 Table 1
 Comparative analysis (continued)

| Reference | Topic | Problem statement | Theoretical contribution | Methodology |
|--|---|---|---|--|
| Deryol et al. (2016) | Crime places in context, an illustration of the multilevel nature of hot spot development | Explore the importance of a multilevel theory of crime places and had implications for more effectively addressing crime | Contribute to increase our understanding of the multilevel conceptual model of crime spots | Multilevel Poisson regression analysis |
| Kester (2013) | Visualisation and analysis of geographical crime patterns using formal concept analysis | Propose a new way of analysing crime patterns by combining Formal concept analysis | Benefit in building a more defined and conceptual systems for analysis of geographical crime data | They used a formal concept analysis to analyse crime patterns and visualised associations between the incidences of various crime |
| Estienne and Morabito (2016) | Understanding differences in crime reporting practices: a comparative approach | examines the correlates of the crime reporting decision in developing nations with newer democracies, newer economies, or developing economies | This research adds to the much-needed literature on crime reporting practices in countries in transition, and developing countries in Asia, Africa, and Latin America | Their developed model was based on using a sample of 23 nations from the 2000 International Crime Victimization Survey (ICVS) |
| Xie (2014) | Area differences and time trends in crime reporting | Using the National Crime Victimization Survey to examine geographic variances and temporal tendencies in crime reporting in New York and other municipal areas between 1979–2004. | Examine the trend of crime reporting Determine views of police helpfulness | Comparing New York with other MSAs on aggregate rates of crime reporting over time. Using crime incidents as the unit of analysis |
| Cook (2018) | Gun theft and crime | The role of theft in supplying the guns used in the robbery, assault, and murder is unknown | Research agenda is proposed that would provide more certainty about the role of theft. | Initial analysis of data on firearms which were reported stolen to the Chicago Police Department |
| Schnell et al. (2017) | The effect of community areas, neighbourhood clusters, and street segments on the spatial variability of violent crime in Chicago City | They intended to replicate a recent study that found that street segments, rather than neighbourhood units of analysis, was responsible for the most significant share of the overall spatial variation of crime | Identify future research of the next wave of 'neighbourhood-effects' research | Scrutinised violent crime incidents using: Linear mixed models with random slopes of time. Micro-units of analysis, such as street segments |
| Rummens et al. (2017) | Predictive analytics in spatiotemporal crime forecasting: | Investigates the potential of applying predictive analysis in an urban context. | | They used an ensemble model, synthesised the results of logistic regression and neural network model based |
| http://time.com/ 4497814/chicago- murder-rate-u-s- crime/ | Crime predictive analysis based on geo-intelligence | Combined use of these techniques can give satisfactory results | Expand our knowledge of analysis of crime using geospatial analysis and geo- intelligence techniques | Two types of analytical techniques Analytical techniques Geo-intelligence methodologies (retrospective and perspective). |
| Stamatel (2015) | How data visualisation can improve analytical thinking in cross-national crime research | They argue that data visualisation techniques – if employed following sound principles of analytical design – can enable data analysis, causal reasoning, and theoretical development. | The presented analysis shows new patterns that were not apparent in the initial analysis and encourages further theoretical thinking. | Reanalyses data from a cross-national analysis o homicide rates Using two data visualisation techniques (mapping and sparklines) |

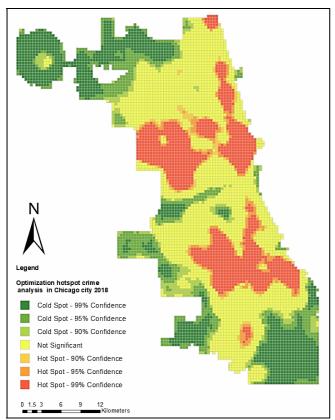
3 Study adapted methodology

This section is devoted to describing the study area; explain the importance of GIS in crime data analysis, and then we describe different GIS analysis techniques that we used in this study.

3.1 Study area

Since the beginning of the twenty centuries, the Chicago police department has been recording and monitoring crime events in Chicago. Unfortunately, the overall crime rates and in particular, the violence crime type is typically higher than the average crime of the USA. Furthermore, in 2016, Chicago was responsible for about half of the homicide crime in the USA, while other states crime rate was low comparatively (http://time.com/4497814/chicago-murderrate-u-s-crime/; http://www.city-data.com/crime/crime-Chicago-Illinois.html.). As such, the causes of this higher statics in Chicago City still not known entirely. Also, there is no united consensus on the cause of these violent crimes (Chamikara et al., 2015). These facts of Chicago crime rate make it an excellent example to explore what we proposed in our study, as shown in Figure 1.

Figure 1 Quick summary of the study area and optimisation hotspot crime analysis in Chicago City 2018 (see online version for colours)



Note: We produced this map using ArcMap 10.6 (Esri, 2018) using the Chicago crime portal data

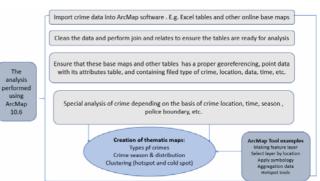
After studying several papers and investigating different methods, we decide to use the following spatial analysis methods to analyse the crime trends in Chicago City. The remaining of this section, we are going to summarise some critical methods that have been used in crime data analysis using GIS.

3.2 GIS importance in crime analysis

GIS is considered as one of the most potent qualitative data analysis technology that increasingly been used to enhance our understanding of crime data. GIS offers rich visualisation output via maps, tables, charts, and other real-time mapping techniques. This paper emphasises on the use of a quantitative GIS-based approach as a primary method of inquiry. According to the reviewed literature, this approach proved to be useful to visualise crime data and to uncover significant patterns that may exist in the selected data.

GIS enables the modelling of the workflow of a crime and captures its best practices. The location of crimes and the connection of those places to one another and other data is a crucial aspect of crime analysis (Olakorede et al., 2017). The significance of crime place or location is going beyond just the location; it goes to cover the different characteristics of those locations and of course, the entire environment in which the crime happens. Accordingly, investigation of spatial data, for instance (streets blocks; street networks, parcel info, orthophotographs, school, business, and residential location) are critical for effective and efficient crime analysis. For example, using a simple map that shows the areas where crimes have occurred can be used to assist law enforcement and direct them to hot spots crime places where they are most likely needed. Alternatively, there is a need to use more complex and intensive data and maps for other involved and sever crime events. In both cases, GIS offers a full potential to meet these needs. The methodology is explained in Figure 2.

Figure 2 Research methodology flow chart (see online version for colours)



3.3 GIS analysis techniques

In this section, we explore some of the GIS analysis tools used to enhance our understanding of crime rates and trends; however, this paper focuses on hotspot clustering analysis.

3.3.1 Survey-based analysis

Criminologists developed a couple of methods that helped in extracting information about the extent and pattern of victimisation and crimes in a society known as the *Crime Survey* and *Victim Survey*. These methods need reliable data to comprehend the nature and location of crimes events adequately. Understanding the spatial pattern of crimes and its affected victims in a particular area will help in identifying the source of these criminal activities for a specific area and then enables law enforcement to make a possible solution accordingly (Olakorede et al., 2017; Shafique et al., 2017).

3.3.2 Identifying hotspots

Hot spots are a fundamental method in determining the area with high crime levels. It primarily identifies spatial clusters of the statically significant low or high-value attributes. There are several methods of hot spots clustering methods such as:

- *Spatial analysis method:* we use this method to check the location, characteristics and connection of features in spatial data among overly and other technical techniques.
- *Interpolation method:* it is useful to predict values at other unknown points.
- *Mapping cluster or spatial autocorrelation:* in which it used an amount of degree to which a set of spatial features and the data values are linked with it.

Hotspot analysis comprises several steps:

- 1 data collection is the fundamental step of implementation
- 2 geo-referencing of the dataset
- 3 digitised spatial features
- 4 mapping the police station and their boundaries
- 5 creating a crime database
- 6 and finally, the hotspot method is applied to the dataset to produce the heat or hotspots crime maps (Ansari and Kale, 2014).

Figure 3 shows the math behind hot-spot analyses of our study hotspot, and Figure 4 shows flow design of the algorithm.

Figure 3 The hot spot analysis tool calculates the Getis-Ord G_i^* statistic

The Getis-Ord local statistic is given as:

$$G_{i}^{*} = \frac{\sum_{j=1}^{n} w_{i,j} x_{j} - \overline{X} \sum_{j=1}^{n} w_{i,j}}{s \sqrt{\left[n \sum_{j=1}^{n} w_{i,j}^{2} - \left(\sum_{j=1}^{n} w_{i,j}\right)^{2}\right]}}{n-1}}$$
(1)

where x_j is the attribute value for feature j, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$
(2)

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_{j}^{2}}{n} - (\bar{X})^{2}}$$
(3)

The G_i^* statistic is a *z*-score so no further calculations are required.

Source: Adapted from Getis and Ord (2010)

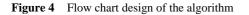
In Figure 3, the G_i^* statistic returned for each feature in the dataset is a z-score. For statistically significant positive z-scores, the larger the z-score is, the more intense the clustering of more significant values (hot spot). While, for statistically significant negative z-scores, the smaller the z-score is, the more concentrated the clustering of small values (cold spot).

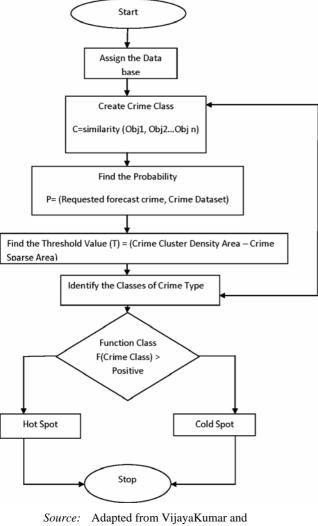
3.3.3 Questionnaire method

Balogun proposed this method to obtain information from the police and the public. Scholarships divulge that people have no confidence in the police. As such, some law enforcement department might find themselves limited to securing information and some of the obtained one might be outdated in which results in restricted sources that necessary in reducing crime. However, GIS resources can bridge this gap and assist in crime analysts to produce: digital land use maps that displaying crime location; crime geospatial database to decrease records redundant; spatial analysis for processing spatial queries; also, GIS can provide both printed and soft copy maps to aid in analysing crime incidents (Balogun et al., 2014).

3.3.4 Used algorithms

While we rely on ArcMap software (Esri, 2018) to create the analyses map, these maps used Fisher-Jenks algorithm to divide the distribution into groups – natural breaks classification: Natural breaks classes are based on natural groupings inherent in the data. Class breaks are identified that best group similar values, and that maximise the differences between classes. The features are divided into classes whose borders are set where there are relatively substantial differences in the data values. This method might be not the most inclusive approach to summarise descriptive patterns of crime incidents over time, but it does offer a useful tool to illustrate differences in the spatial distribution of crime incidents (Slocum et al., 2008).





Alhadidi (2014)

3.3.5 Risk terrain model

Risk terrain model (RTM) demonstrates a map that defines the spatial properties of an area (https://crimemapping.info/). In RTM, distinct map layers are produced, which represents the spatial phenomena of an area. At that time, thematic layers will be added to generate a mixed risk terrain map with values that determine the spatial influence of all features at every location through the landscape. This method helps in explaining the spatial pattern together with identifying the hot spots area.

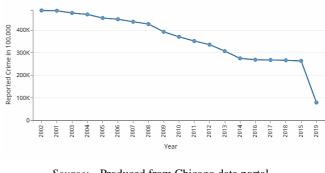
4 Results

We report the significant trends and results of the analysis, including statistical descriptive, crime visualisation by showing the outcome analysis through plotting maps that we produced using ArcMap 10.6.

4.1 Statistical descriptive

We used the different statistical analysis software such as Tableau 2018.1, Qlik sense desktop and the opensource Chicago data portal (https://data.cityofchicago.org/Public-Safety/Crimes-2018/3i3m-jwuy) visualisation tools to conduct the statistical analysis of Chicago crime date from 2001-2018. The data were grouped from its source based in five years intervals. We managed to retrieved crime data from the Chicago police department for the following period: 2001–2004; 2004–2007; 2008-2011; and 2012-2017. Then we combined all of these data files to represent the crime trends from 2001 to 2018, as shown in Figure 5.

Figure 5 Chicago reported crime (rate per 100,000) between 2001–2019 (see online version for colours)



Source: Produced from Chicago data portal (https://data.cityofchicago.org/Public -Safety/Crimes-2018/3i3m-jwuy)

As illustrated in Figure 5, the crime rate in Chicago City is decreasing gradually, and this result aligns with previous studies (Institution for Social and Policy Studies, 2013) of Chicago crime rate index. To validate that, we include a crime rate index for Chicago City in Figure 6.

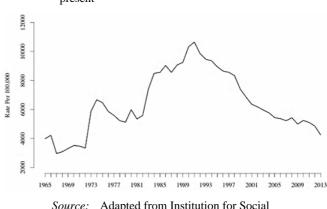


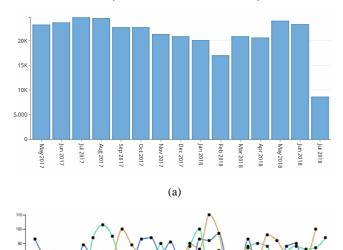
Figure 6 Index crime in Chicago (rate per 100,000), 1965 to the present

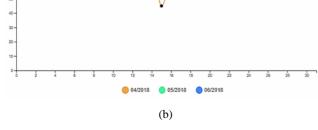
urce: Adapted from Institution for Social and Policy Studies (2013)

Figure 6 shows another proof of the steady decreases in crimes monthly arrests in the last 14 months. This is a positive indicator of the general trends but again we out to be careful by noting that even there is a decrease, but Chicago still has the highest crimes rated in US cities.

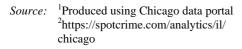
Although, there is a crime decrease that happing in Chicago due to the efforts of police departments and other government and non-government efforts to mitigate and prevent crime occurrence, but in fact, the crime rate in Chicago City is high compared to another US city.

Figure 7 Monthly arrests in Chicago, 2017–2018, (a) monthly crime distribution¹ (b) Chicago crimes in the past three months² (see online version for colours)





Note: May had the most number of crimes in Chicago.



Also, there is a large monthly variance of crime occurrence, to show that we include the monthly crime rate, as shown in Figures 7(a) and 7(b). May record the highest month of crimes in Chicago, Illinois. For example, May month had about 1% more crime than April, with May creating 3,483 more crime incidents than April. Also, it had about 1% more offence comparing to June, with 493 more crimes than June. These monthly numbers are suggesting that even though there is an overall decreasing in crime trends based on Chicago crime index, however, crimes are produced daily in Chicago which makes us recommend keeping

tracking crime rates and figuring out some new ways of controlling crime. One may question, what are the significant factors that reasonable about crime occurrence in Chicago? Some factors related to employment, weather, social segregations, and much more. Digging for these significant reasons may go beyond the scope of this study, but we point out about the importance of reliving the reasons of crimes and attempting to ensure the equality in the Chicago communities will be the key to start preventing crimes. Not to forget to mention that there is a real need to legislate guns ownership in this city, and it is another critical reason that contributes to the highest crimes at the national level.

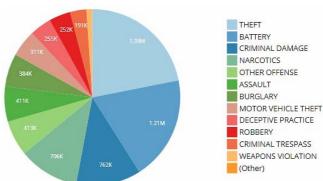


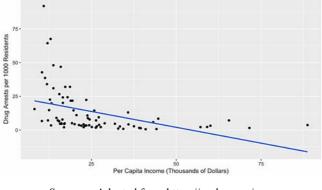
Figure 8 Chicago primary crime numbers in millions and hundred thousand (k) based on their type in Chicago 2001–2018 (see online version for colours)

There are several types of crimes as can see in Figure 8. Crimes were branded using the Illinois Uniform Crime Reporting (IUCR) code as provide in this study dataset and are summarised below.

Between 2001–2018, theft was the most commonly committed crime in Chicago as of 1.39 million cases. As shown in Figure 7, battery recorded 1.21 M case, criminal damage 761,000, narcotics 706,000, assault 411,000 and burglary 411,000 were also commonly committed crimes throughout Chicago's community areas. Also, other offices were 412000; these other offences suggest that there is a need to identify and classify what others mean here, this can be done by improving the input data entries and attempt to be as specific as possible since we are talking about almost half million cases here.

The narcotics-related crimes are also among the most common in Chicago since it is directly related to drugs. One may ask about the relationship between drugs trade activities and low-income areas. Do drug arrests more in these areas. Previous attempts were made to answer this question (https://rpubs.com/ry_lisa_elana/chicago), the author compared drug arrests (per 1000 residents) in 2012 to per-capita income in each of the Chicago community areas as illustrated in Figure 9 shows that there is a significant negative correlation between drug arrest rates and incomes in Chicago's community areas. In other words, the higher rates of drug arrests occurred in lower-income zones, whereas the more upper-income neighbourhood had, the lower drug arrest.

Figure 9 Seven drug arrests (per 1,000 residents) compared to per-capita income in each of the Chicago community areas (see online version for colours)

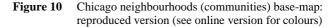


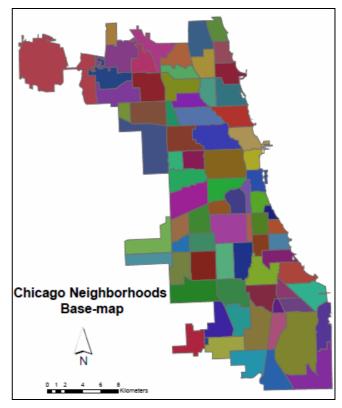
Source: Adapted from https://rpubs.com/ ry_lisa_elana/chicago

4.2 GIS analysis

GIS became one of the best analysis and visualisation tools used by most of police and security department to control, plan and mitigate crimes because of its ability to improve crime investigation by offering excellent insights to support the decision-making process. The outcomes of GIS Analysing are in the form of crime mapping as we did in this study. We can map and plot related issues and factors that are directly related to crime rates and its future trends too. For example, hotspots maps show the full area where the crime took place, and this helps to draw the police department attention to focus their efforts on controlling their area and distribute their resources accordingly. Also, the cold spots area asset people and other businesses activities to expand their operations within a safe environment. Also, the place of crime occurrence is essential as well as the characteristics of the neighbourhood (streets grids, alcohol stores location, socioeconomic status, high residential movement, ethnic heterogeneity, school locations, business locations), all in which are equally important in explaining and predicting crime trends within a specific location.

To perform and plot crime events analysis, we prepared a base-map for the study area Figure 10. There are 80 neighbourhoods (communities) within Chicago City. This base-map includes boundary files as main layers then we added Chicago crime data after cleaning and preparing the data to be compatible with ArcMap environment. Then we perform various spatial analysis operations to produce several crime maps such as density maps, hotspots maps; crime distribution maps and other visitations, which all assists in better-visualising crime rates and trends within Chicago City. This preparation phase is essential to extract information from crime data and then to convert this information into insights to enable decision maker and another stakeholder to make sense and use of such data. We visualise the available data using ArcMap 10.6 to map the following illustration about crimes in Chicago from 2001-2017.





We start our analysis by exporting the crime data excel files into the ArcMap environment to prepare the analysis. Then we generate the flowing maps as seen in the following Figures 11–14.

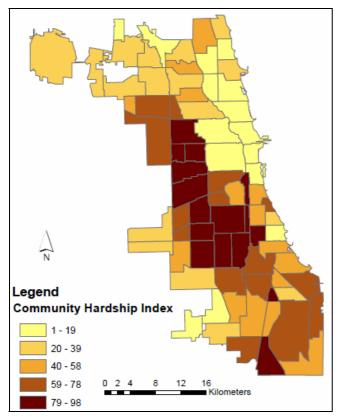
4.3 GIS output analysis examples

4.3.1 Community hardship index

Hardship index is an amalgamation of the following factors: Percent of crowded housing; percent of households below poverty; unemployment rate 16+, percent aged 25+ without a high school diploma; percent aged under 18 or 65+ and per capita income (Chicago Magazine, 2012).

Figure 11 shows that the community area with high hardship index located in the middle south and the south, such as the Riverdale and Fuller park city with scores range from 79-98. Fuller Park also has a high level of poverty 55% below the poverty line and up to 40% of unemployment with a meagre income of \$11,455 per capita. Though, the north side and northeast parts of Chicago City have the lowest hardship index located in the 1–19 range.

Figure 11 Communities hardship index (see online version for colours)



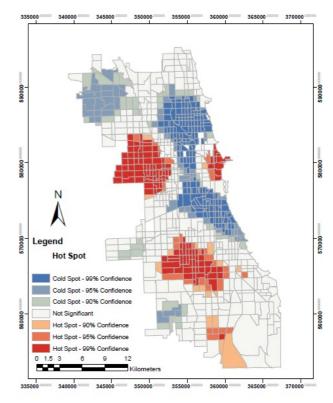
Notes: The Chicago Public Health created this hardship index from six socioeconomic indicators for 2008–2012. Each Chicago community area has its hardship index value. The index is based on the following indicators: % of occupied housing units with more than one person per room; % of households living below the federal poverty level; % of persons aged 16+ that are unemployed; % of persons aged 25+ without a high school diploma; % of the population under 18 or over 64 years of age; and per capita income. The scores are standardised for these 77 communities only.

Source: This map reproduced from ArcMap 10.6 through its online server (Esri, 2018)

4.3.2 Crime hotspots

The crime hotspots show that some areas are more susceptible to crime occurrence than the other locations. We can see from the hot spot map Figure 12 that displays the location of crime occurrences; this offers a seamless way of visualising crimes instead of searching through these events individually. This function provides a quick response and can inform the decision maker of the necessities of action within these areas, and we can optimise the map to show information within a specific time range.

Figure 12 Chicago crime hotspots 2002–2018 (see online version for colours)



Note: Feature service generated from running find hot spots toolbox in ArcMap 10.6.

Figure 12 depicts the graphical interpretations of the crime hotspot detection. The hotspots analysis tools are calculated using ArcMap 10.6, which estimated the Getis-Ord Gi statistic for the selected Chicago crime dataset.

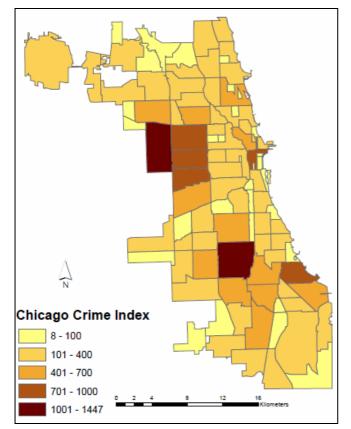
As explained in the Arc GIS official website: "The resultant z-scores and p-values tell you where features with either high or low values cluster spatially" (Chicago Magazine, 2012). This technique works by considering each teacher within the context of adjoining features. Which mean that the high-value feature may not be statistically significant. However, a great feature that surrounded by another high values feature will take only one to be considered a statistically significant hot spot. In the case of positive z score, the higher the z score, the more intense the clustering of the hotspot, while in the case of negative significant z scores, the smaller the z score, the more intense clustering of cold spot (Chicago Magazine, 2012)

In term of the workflow that we used to optimise Hotspots result, there were 388 valid input entries. The total study area was 80,452,228.3206 metres. There were four outlier locations, which were not used to compute the polygon cell size. The polygon cell size was 483.0000 Metres. The analysis was performed on all polygon cells within the boundary area layer. The aggregation process resulted in 649 weighted areas.

4.3.3 Chicago crime trends

GIS analysis methodology analysis has great implications in term of recognising and shedding lights on the doubtful occurrences and events that possibly will require further police investigation. Moreover, GIS is a useful tool in educating an individual with visual information about crime rates, concerns and forecasting potential risks of crimes based on the previously recorded trends, in other words, GIS empower public with evidence and knowledge to drive their action towards solving and mitigating crimes occurrence. In Figure 13, we show the crime index in Chicago City.

Figure 13 Chicago crime index (the spatial distribution of violent crime incidents in Chicago per unit of analysis) (see online version for colours)



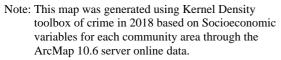
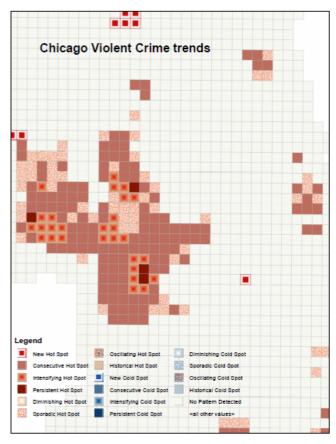


Figure 14 shows the crime violence trends in Chicago City. One can see the further classification of the hotspots such as a new hotspot, intensifying hotspots. Also, it shows other cold spots where the crime is relatively very low or did not take place at this location. Overall, Chicago has a high crime rate of 44/thousand individuals, which make it one of the most top crimes rate in America. According to Neighbourhood Scout's analysis of FBI reported crime data that one in ninety could be a victim of violent or property crime (https://www.neighborhoodscout.com/il/chicago/ crime). Understanding crime rates and types are essential in the efforts of controlling or illuminated overall crimes in Chicago.

Figure 14 Chicago crime violent trends 2017–2018 (see online version for colours)



Note: We pulled data from Chicago's open data portal of data, made public by the Chicago Police Department's Citizen Law Enforcement Analysis and Reporting (CLEAR) system.

4.4 Highlights

The finding of this study showed that using GIS is a much convenient and excellent means of crime mapping analysis. One can visualise the crime pattern and trends about the crime geographic location. GIS software offers unique geographic referencing abilities and capability to use mapped information in crime prevention controlling management in Chicago and other places in the world. In this study, crime maps are generated to visualise the hotspot, crime trends and crime type and additional insights which are proven to be useful for both police and other private sectors.

- This study also shows that theft or robbery is the dominant crime type that is commencing day by day. Then battery crimes were coming from the second primary type of crimes.
- Chicago seems to be on course to have both the lowest violent crime rate since 1972, and lowest murder frequency since 1967.

- Early data from the last five years shows that the Chicago index.
- Crime rate will continue to decrease steadily.
- Chicago has seen a robust drop in most crimes over the last three years in compares to the previous crime index data.
- Crime naturally upsurges during summer months and declines during winter months. That is an overall crime trend and is not explicit to Chicago.
- Chicago is the most studied city in all the criminology-related subjects. Chicago has similar crime phenomena and patterns since the 1930s.
- According to Shaw and McKay's social disorganisation theory which is based on their study of Chicago crime in the 1930s by mapping out early crime in Chicago and they originate that the crime rates were uppermost in the same neighbourhoods of Chicago City (Bellair, 2017). Interestingly and after several decades of studies and analysis of Chicago crimes, most of the studies show that the same communities of highest crime Unfortunately still experience the mainstream of crime. One can go back and compare the crime pattern of those 1930s study and will find it very typical.

5 Discussion on results and implications

This section will summarise the important overarching themes that we learn from this paper analysis; we report the most critical and relevant implications.

5.1 Benefits of combining GIS and another visualisation tool in crime analysis

As we know, there are many traditional tools that crime data analysis and visualisation. However, by applying GIS techniques, one can:

- 1 Generate a single output analysis in which, it integrates several themes or layers into one single meaningful map, which is useful to interpret the crime rates and trends results. From our analysis, we saw, for example, the relationship between housing intensity, hardship and other demographic factors in which we can explain why crimes are concentrated at particular hotspots. The interpretation is essential to draw a police department attention to where they can allocate their policing resources effectively. Also, this helps urban planners of metropolises re-plan or modify the city growth and directed to other location that is safe and less population density.
- 2 The availability and capabilities of GIS make it accessible and efficient to be used by the police forces around the world.

3 GIS offers an excellent management functionality of the crime information, built environments characteristics (location, streets, the point of interests) and other socio-demographic data, GIS permit operative combination and analysis of this information to recognise, capture, and stop or mitigate suspicious activities.

Overall, the central forte of GIS over other crime analytical methods is the capability to envisage, examine and elucidate the unlawful action in a spatial context.

5.2 What is special about using GIS tools

Using GIS analysis techniques has been utilised by the police force to track crime events and to generate crime density maps. Nowadays with the availability of crime data and the development of GIS and other visualisation techniques, law enforcement used them to enhance the spatial data analysis of crime pattern, enhance emergency response and optimise police resources allocation (http://www.esri.com/news/arcuser/0405/ss_crimestats1of2. html). We summarise the major functionalities of addling GIS to existing visualisations in the following:

5.2.1 Identifying the location of crimes accurately

Crime hotspots are a great way of displaying crime pattern and trends and its relation to space. This GIS output map is essential in communicating the crime information with the public and assist in allocating police recourse when planning. Hotspots are a valuable tool not only to identify a location with high crimes but also investigating various elements that may explain why these locations have a high concentrated rate of crimes. All of this contributes to enhancing law enforcement to be more efficient and have a wise crime prevention decision.

5.2.2 Carrying out risk assessment

The higher density area with more people live on would potentially have more crime incidents comparing to smaller density population area. City neighbourhoods are a complex landscape that has several physical and human characteristics that are working together toward understanding crime occurrence and could be effectively used in education public about crimes, assisting police in tracking and monitoring these neighbourhoods. However, these characteristics are hard to quantify or comprehended separately, but with the use of GIS spatial analysis tools, one can display all these characteristics as layers and make it ready to present the relationship among them and crimes control and further urban planning.

5.2.3 Finding inklings to criminal events

Investigating the distribution of crimes types is essential to step to comprehend the trigger factors behind criminal events. For example, GIS offers a crime analysis the capability of knowing the mean centre for each crime type and how that centre shifts by evaluating crime actives during the night-time and daytime. GIS offers a tool named Mean Centre tool, which used to quantify the average of x and y coordinates for each crime type within the selected area. Knowing this information may be used to improve the redness of the police department.

6 Future work

As a future extension of our work, we one could apply more classification models to increase the accuracy of crime prediction and to improve the overall crime prediction and prevention performance. It is also helpful to consider including all the urban physical and human elements of Chicago City in order to explore the potential association between these neighbourhoods elements and their crime rate.

Moreover, future studies may study the crime in Chicago City crime in term of the following:

- Using real-time date tracking to keep law enforcement agency who is on duty updated and to visualise hotspot/ noticeable crime activities
- Optimise the government police department resources by using previous crime analysis result to distribute their policing resources accordingly
- Open a new department unit that is responsible only for reporting and offering a real-time map that is updated 24/7 in order to control and track suspicious activities before the crime occurred.
- Revitalise community safety watch programs and arm them with the most efficient reporting tools using their own devices.

7 Conclusions

The present study confirmed the efficiency of the Geographic Information System and other visualisation techniques as a tool in scrutinising crimes in Chicago City. Chicago is the most studied city in all the criminology-related subjects. Chicago has similar crime phenomena and patterns since the 1930s. The outcome of this study disclosed that using GIS is a much suitable means of crime mapping analysis for its ability to visualise the crime pattern and predicting crime trends concerning a specific geographic location. We generate several crime maps to envisage the hotspot, crime trends and crime type. This study also displays that theft or robbery is the central crime type that is commencing 24/7. Then battery crimes were coming from the second primary type of crimes. We conclude that Chicago seems to be on course to have both the lowest violent crime rate since 1972, and the lowest murder frequency since 1967. Chicago has seen a vigorous drop in most crimes over the last three years in compares to the previous crime index data. Another impressive result that crime naturally upsurges during summer months and declines during winter months. That is an overall crime trend and is not explicit to Chicago. Remarkably, we conclude that after several decades of studies and analysis of Chicago crimes, most of the studies (as mentioned above) proof that the same communities of highest crime rates still experience the mainstream of crime.

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