FACULTY OF SCIENCE, ENGINEERING AND AGRICULTURE

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL SCIENCES

GIS-BASED SPATIO-TEMPORAL ANALYSIS OF CRIME PREVALENCE IN THULAMELA LOCAL MUNICIPALITY

BY

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ABSTRACT

Crime is a serious problem with high social and economic costs in South Africa. It is neither unique nor random, but rather tends to be unevenly distributed and has a spatio-temporal pattern. The aim of this research is to analyse the spatial and temporal distribution of crime prevalence in Thulamela Local Municipality using Geographic Information Systems (GIS).

GIS applications were used to open new opportunities in crime control and prevention. The spatio-temporal distribution of crime in Thulamela Local Municipality was analysed using GIS tools. This research study adopted both quantitative and qualitative approaches to produce a more comprehensive study of the spatial and temporal distribution of crime in Thulamela Local Municipality. Data was analysed for various argumentations, i.e., spatial distribution of crimes, temporal trends, and identification of hotspots.

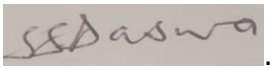
A Hotspot Analysis (Getis-Ord Gi*) tool was employed to unveil spatial clusters of crime prevalence. The analysis pinpointed distinct hotspots where crime incidents were significantly concentrated. The present study has found that crime incidences are influenced by various factors such as alcohol and substance abuse, domestic violence, illiteracy, poverty, unemployment, and self-enrichment. Thohoyandou was found to be one area with a high crime prevalence compared to Tshaulu and Mutale. Crime analysis did not only deepen our understanding of crime patterns, but also provided actionable insights on the types of crimes that happen in the different areas. By employing a diverse array of spatial and temporal analytical tools, I unearthed trends, clusters, and causative factors, understanding the socio-economic factors that play a role in the number of criminal activities that happen all over the country. As we continue to grapple with the multifaceted challenge of crime prevention, this comprehensive analysis serves as a foundation for data-driven strategies that can enhance public safety and well-being in Tshaulu, Mutale, Thohoyandou, and similar regions.

Keywords: Crime hotspot; Crime patterns; Crime prevalence; Spatial and temporal analysis; Thulamela Local Municipality

TABLE OF CONTENTS

DECLARATION

I, **Shumani Samuel Daswa**, hereby declare that the dissertation for the degree of Master of Environmental Sciences at the University of Venda, hereby submitted by me, has not previously been submitted for a degree at this or any other institution, that it is my own work in design and execution and that all reference material contained therein has been duly acknowledged.

Signature...  Date.28.11.2023

DEDICATION

I dedicate this to my beloved late son, Rabelani Tilly Daswa. This thesis stands as a heartfelt tribute to the unwavering encouragement and motivation you instilled within me. Your enduring belief in the pursuit of knowledge continues to resonate deeply, fuelling my academic endeavours and guiding my path. This thesis is a token of profound gratitude and a testament to your enduring influence on my academic journey. Your unwavering support remains a constant source of inspiration, propelling me forward as I dedicate these findings to honour your profound impact on my academic pursuit.

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LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background to the study

Crime in general reflects socio-economic characteristics and demographic details of an area, which assist in analysing the causes of crime (Rummens et al., 2021). Crime takes place where there is a convergence of the will to offend, a vulnerable victim, and an environment that provides the opportunity for the offence (Brontinghom et al., 2013). The government generally knows that the threat of crime creates an environment of fear and anxiety in society and often prevents people from engaging in their daily activities. The legacy of apartheid policies in terms of socio-economic activities and interracial inequalities suggests that ethnicity is still an important factor in the risk of being a victim (Stevens, 1998). Such kinds of inequalities make South Africans dissatisfied with their day-to-day personal safety. Historical victim surveys have shown that African and coloured South Africans have a greater possibility of being victims of individual violent crimes, while whites have a higher risk for property-related household crimes (Schonteich & Louw, 2001; Mpata, 2011; Enaifoghe et al., 2021).

The levels of crime continue to be of serious concern in South Africa, regardless of the Constitution of South Africa (Act No.108 of 1996), which states that everyone should be protected from all forms of violence, whether from public or private origin. Despite the measures in place to combat crime, it continues to be a serious challenge for the victims and crime prevention units. It is estimated that about 7944 households in Thulamela experienced housebreaking in 2009, while a further 5698 households were victims of home robbery, making it the most prevalent household crime (SAPS, 2006). Although these crimes have long been feared by households, they remain largely unreported to the police, thus distorting the true magnitude of crime in the municipality (SAPS, 2006).

The alarming rate of crime prevalence in the pre- and post-democratic eras, without considering its spatial and temporal distribution, brought a serious challenge to safety and security services departments such as the South African Police Service (SAP). One such challenge is the inability to pinpoint the location and time of crime occurrence, which may add error to the analysis. The implementation of Geographic

Information Systems (GIS) as a tool in dealing with spatial and temporal analysis of crime prevalence contributes to adding value on ways to combat or fight crime (Ferreira et al., 2012). Spatial and temporal data analysis helps one analyse crime prevalence and better understand not only why a crime occurs but also where and when that crime is occurring.

With respect to direct measures to improve safety and security, the government's social development program may also indirectly impact on the levels of crime. For instance, one of the primary commitments made by the government is the provision of, and improved access to permanent housing that provides secure tenure and protection against elements as described in the Housing Act 1997 (Act No. 107 of 1997). In the 2022 General Household Survey (GHS), there has been a significant improvement in the nature of dwellings in which people live, including access to various basic services and facilities, and a significant increase in the number of individuals and households that benefit from social grants. All these provide an important indication of the well-being of the household members.

Although it is debatable whether poor living conditions lead to crime, shelter satisfies a basic human need for physical security and comfort. The quality of life is sometimes affected by the level of crime, and the fear of crime has a huge impact on people's wellbeing. This makes crime to further contribute to the economic impoverishment of the nation (Chambliss, 1975; McGahey, 1986). Moves to boost community confidence in the police and to enlist cooperation in law enforcement include the establishment of community crime forums. Efforts are underway nationally to engage communities in assisting with policing to ensure that the service is more efficient, and crime does not pay (Maqsood et al., 2019). The three fundamental facts that underpin the analysis of crime in South Africa include different kinds of crime, which require many different types of intervention; the cause of crime, making it necessary to understand the linked socio-economic, political, and psychological causes in order to prevent it; and crime statistics, which are notoriously unreliable, so simple statistical analysis can hide as much as it reveals (Mulamba, 2021). In order to develop effective solutions, crime and its causes must be disaggregated.

For a proper understanding of crime in South Africa today, we must combine an analysis of crime statistics with information gathered in other ways. We tend to be less demanding of the Department of Justice and Constitutional Development (DoJ & CD) and likewise, the Department of Correctional Services (DoCS) to provide accurate statistics. The official statistics available to the public do not reflect the true crime picture and should not be used exclusively in decision-making or evaluative processes (Singh, 2016). As for the report on the 1996 Nedcor Report on Crime, Violence, and Investment, it was warned that the official crime statistics mostly reflected only crimes reported to the SAPS and that the rate of underreporting is believed to be as high as 50%. Similarly, in the survey of 1 075 households carried out in Soweto, Johannesburg, it was found that a total of 43% did not report violence-related crime to the police (Lekoba et al., 1998). The national crime victim survey conducted by the Institute for Security Studies in 2003 confirmed that less than half of all the crimes committed were reported to the SAPS (Singh, 2016).

Nonetheless, there was a large variation in the incidence of violent crime between provinces, municipalities, cities, and per neighbourhood, and the poorest communities bear the brunt of this burden. Most people residing in KwaZulu-Natal (KZN), Gauteng, and the Western Cape run a greater risk of violent victimisation than those living in other provinces of South Africa (Van der Hoven & Maree, 2005). The crime committed in Gauteng is at epidemic levels, with about 5 073-armed house robberies (13 per day), 6 890 car hijackings (23 per day), 41 170 vehicle thefts, and 80 116 house burglaries (219 per day) reported between April 2005 and March 2006 (SAPS, 2006).

Despite that, regardless of what the statistics indicate, the feelings of personal safety have declined markedly since 1998 and fear of crime among the general public has risen substantially (Stephenson et al., 2023). The major contributors to the perception that crime is on the increase are found in personal experiences of crime and negative reports in the media (Campedelli et al., 2020). As a result, multiple or repeat victimisation can affect reporting behaviour in many ways. Repeat victims may decide not to report crimes to the police because of the following reasons:

• Most repeat victims might have learnt how to cope with the consequences of crime either by using neutralisation techniques such as fatalistic acceptance or trivialisation (Rai et al., 2023), or by taking the issue into their own hands (Geldenhuys, 2020).

• Most repeat victims may have had unsatisfactory responses from the police when previous incidents were reported (Ziehgenhagen, 1976).

• Repeat victims may even fear or dislike the police more than single-incident victims do (Skogan, 1994).

1.2 Problem Statement

Crime has been one of the most critical issues facing our communities today. Almost one in ten people fall victim to crime, and as such, this affects the safety of residents across the study area. According to Muhammad et al. (2021), crime scenes vary with place and time, and it depends on a range of factors, including the type of crime and the familiarity between offender and victim or target. Although crime is committed at different places and times, there is still a lack of studies done on analysing and monitoring crime prevalence. Due to high crime reports in South Africa and particularly in the Vhembe district, the researcher seeks to find innovative ways in dealing with crime by looking at crime hotspots for active policing on those areas. Therefore, this study provides measures for monitoring crime scenes such as assault, housebreaking, pickpocketing, murder, and robbery using GIS as a tool in Thulamela Local Municipality.

1.3 Research Aim and Specific objectives

1.3.1 Main Objective

The main aim of the study was to analyse using GIS the spatial and temporal distribution of crime prevalence in Thulamela Local Municipality between 2015 and 2019.

1.3.2 Specific Objectives

- To determine the crime hotspots and spatial distribution of crime prevalence and their characteristics such as housebreaking, pickpocketing, murder, and public violence in Thulamela Municipality.
- To analyse temporal trends in crime prevalence from 2015-2019.
- To identify factors that influence crime prevalence and crime risks.

1.4 Research Questions

- Where and when is the incident of crime event taking place?
- Why is the crime event taking place? Factors influencing such crime events?
- How are the crime events distributed and determined in Thulamela?

1.5 Significance of the study

The study provides crime analysis tools to describe, demonstrate, interpret, and explain the sociocultural, economic, geographical, and environmental context within which certain types of crimes are concentrated in Thulamela communities. However, this study emphasizes the location and distribution of crime scenes occurring in the Thulamela Municipality by monitoring the so-called “hotspots”. The results of this study will be used as a reference by law enforcement agencies in providing evidence-based spatial and temporal intelligence that police can employ to reduce crime and violence in the Local Municipality.

1.6 Description and delimitation of the study area

The study area of interest for this research was restricted to the police-serviced areas, where some were nodal points, growth points, and local service centres. Thohoyandou and Sibasa are nodal points; Tshilamba is a growth point, whereas local service centres will be Mukula and Tshaulu. Thulamela Local Municipality is a Category B municipality established in terms of Local Government Structures Act number 117 of 1998 (Thiba, 2019). It is one of the four local municipalities comprising Vhembe District Municipality in the far north of Limpopo Province. Thulamela Municipality shares the boundary with Collins Chabane Local

Municipality in the east while sharing the borders with Musina Municipality in the northeast and Makhado Municipality in the southwest.

Thulamela is the smallest municipality of four in the district, making up 10% of its geographical area. It is located between 22^0 57' S and 30^0 29' E and covers a total area of 2 893 936 km^2. The municipality has a total population of 497 237 people, according to the 2016 Stats SA community survey, and is the largest municipality in the province in terms of population. It is also the second largest of all the municipalities in Limpopo Province when it comes to population. The name Thulamela is a Karanga word meaning 'the place of giving birth'. Thulamela Municipality is a municipality area covering a vast track of lands, mainly tribal, and Thohoyandou is its political, administrative, and commercial centre. The land in Thulamela is very fertile and good for agriculture. Its large part falls under the tribal authorities, and this makes it difficult for new developments to take place.

Study area Maps.

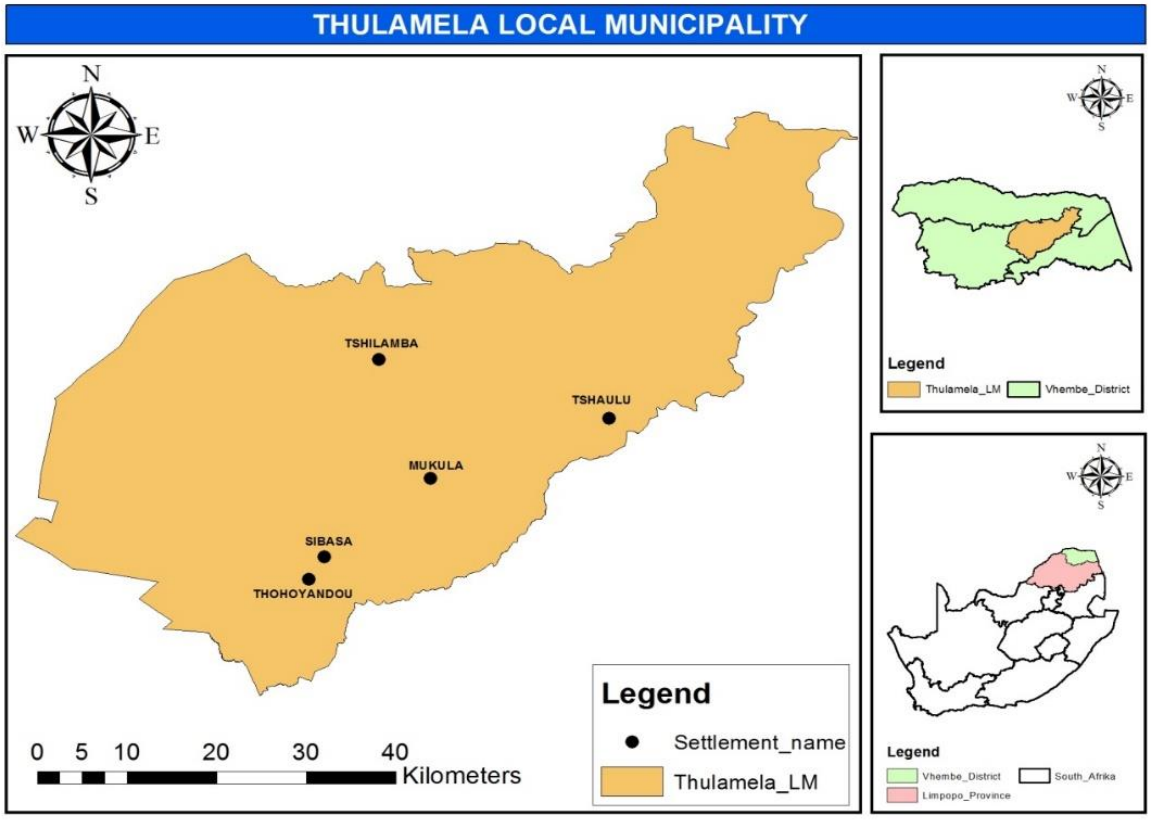

Figure 1: Map showing Thulamela Municipality with areas where police stations are located in the Vhembe district municipality.

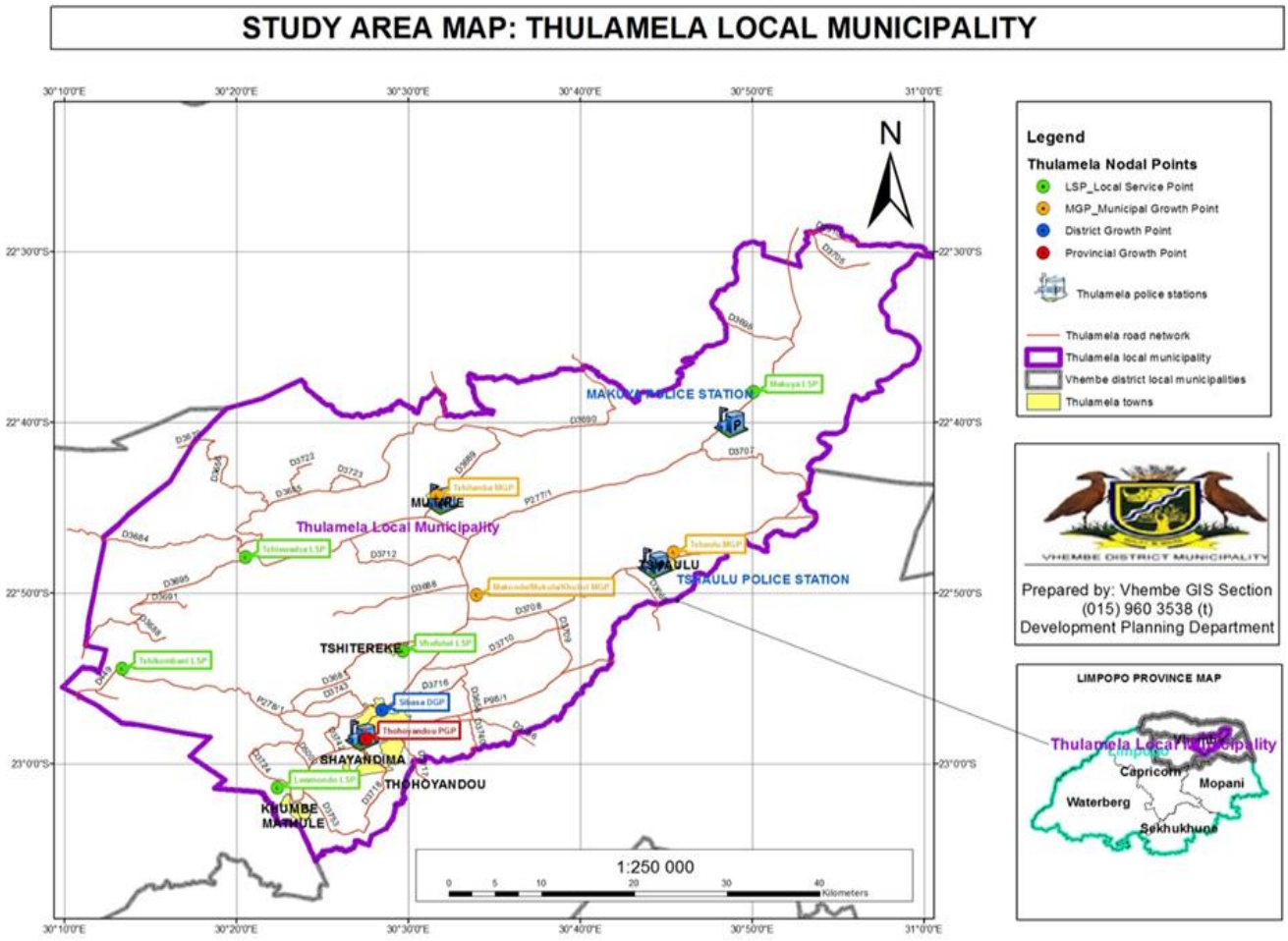

Figure 2**:** Study area map showing Thulamela local municipality with sampled police stations and villages

CHAPTER 2: LITERATURE REVIEW

A crime is an action that triggers an offence and is punishable. According to Olokooba et al. (2018), a crime is an act, default, or conduct that is prejudicial to the community or the commission and, by law, renders the person responsible for punishment by a fine, imprisonment, or other penalty. A vast number of GIS-based crime prevalence studies have been done across the globe, and this literature review section aims to explore and give an overview of the research and studies done elsewhere. The following aspects are discussed in this chapter: crime theory and crime places, crime and victimization driving factors, previous models used for crime analysis for GIS-based studies, crime risk factors, GIS in crime analysis, spatial and temporal analysis: A view from a GIS perspective, hotspot analysis, and crime prevention strategies. The crime theory and crime places, spatial and temporal analysis, Geographic Information System (GIS) in crime analysis, predictive crime modelling, hotspot analysis, risk terrain modelling concepts and theoretical approaches, and Thulamela Local Municipality's criminal activity risk factors are also discussed in this chapter (Tanner-Smith et al., 2013). This chapter also provides an overview of research and studies done on criminal activities such as burglaries, contact crimes, robbery, car hijacking, kidnapping, and public violence and their spatial influences on crime events.

2.1. Crime Event Theory and Crime Places

This section explains the theoretical literature of three crime theories that are believed to have played a huge role in the understanding of crime prevention. The theories discussed below are rational choice, routine activity, and crime pattern theory. Rational choice theory is a theory that seeks to explain the importance of a place to offenders. This theory suggests that offenders tend to pick certain locations that they think favour their motives to achieve their criminal activity's goal (Cornish & Clarke, 2016). There is debate amongst researchers about this theory; others claim that the theory cannot be tested, while others believe it can be (Vasquez et al., 2020). Although there is an ongoing debate about the theory, it is believed that the rational theory can be used together with the routine theory discussed below (Rhodes & Conly, 2017).

The routine activity theory suggests that crime event occurrence is a combination of a number of various factors, such as a motivated offender, desirable target or victim in place and that the target, must be at the same place, at the same time (Rhodes and Conly, 2017; Ljungwald and Elias, 2010). The crime pattern theory merges the above-mentioned theories to help the distribution of criminal activities in an area. This theory seeks to unpack the relationships and interactions between offenders and victims and their surrounding environments (Ljungwald & Elias, 2010). Brantingham and Brantingham (2019) note that one of the most important aspects of crime is the location. The place of a crime and any other geographic information connected with a criminal incident can give a lot of information about characteristics of possible criminals, assist in the design of prevention, assist in the assessment of programs, and help get a better perspective of environmental reasons that may be related to criminal incidents.

2.2. Crime and victimization driving factors

There are numerous driving factors responsible for increased levels of crime and victimization. These factors are also fuelled by a number of factors and conditions that play a critical role in the lives of individuals and the environment they are brought up in (Newman, 1980). Factors influencing crime can be studied, and the results can be used to determine various factors related to different types of crime. By so doing, effective strategies and programmes can be developed and put in place to effectively eradicate crime. This can significantly decrease and prevent certain types of criminal offences and victimization fuelled or influenced by certain types of factors studied (Newman, 1980). These factors are therefore referred to as risk factors. As mentioned above, there are several factors that influence crime and victimization, and they include the following: changes in global trends which play a critical role in the socio-economic dynamics in various countries; factors affecting individuals' local environments, neighbourhoods, and countries; factors related to family and close friendships and factors that affect individuals. These risk factors are illustrated by Figure 3 below. These factors are generally termed risk factors.

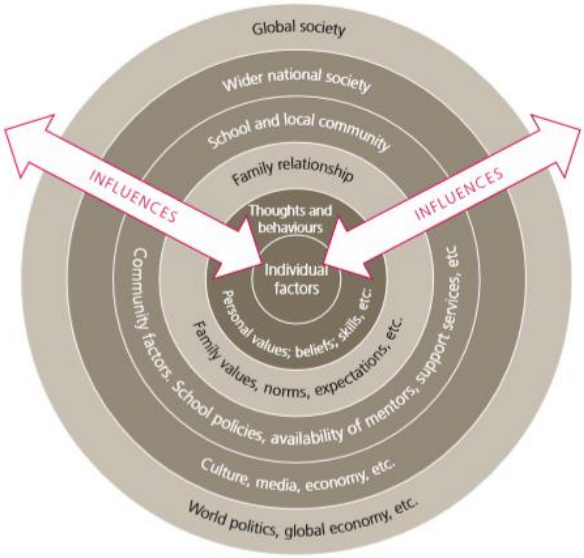

Figure 3: Factors influencing the risk of crime and violence (UNODC, 2010)

The world's population has increased and continues to rise at a rapid rate. As a result, there are major population movements, migration, urbanization, environmental disasters such as those caused by climate change, economic recessions, changes in economic patterns, and changes in organised crime patterns because of the high increase in the world's population (Flango & Sherbenou, 1976; Malik, 2016). These events play significant roles in determining the political, economic, and criminal activities of a country. Such events can also affect governments governing capacity. These events can compromise governments 'ability to govern and, as a result, pave the way for criminal activities such as drug trafficking, gun trafficking, and human trafficking. These types of crimes can increase the high levels of crime, victimization, and violence in vulnerable countries (UNODC, 2010; Malik, 2016).

The vast majority of countries have challenges in balancing wealth and resources, more especially between the rich and the poor, and as a result, the rich get richer, and the poor get poorer. This income gap between the poorest and the richest is a matter documented in many studies. A study done by UNODC in 2010 suggests that a country's infrastructure, quality institutions, income gap between the rich and the poor, population, levels of corruption, and social and cultural patterns pave the way for conditions that may increase the risk of crime and victimization. This is better

outlined by the Gini coefficient, which measures the income quality within a country. This is a very essential tool for measuring levels of desperation in various countries (UNODC, 2010).

The risk factor concept emphasises the roles that deleterious factors play in the increase of criminal activities and victimization. However, criminal activities and victimization levels can be significantly reduced if certain measures, such as examining the resilience of communities, are taken (Dutton & Greene, 2010). Therefore, the positive factors can be yessed to build resilience within communities and individuals. Positive factors include effective and fair leadership, effective and transparent records of criminal justice systems, and funding for various forms of social, environmental, and economic programmes. Appropriate resources such as adequate education and job opportunities, strong community links, and working relations with religious groups play a significant role in eradicating criminal activities and victimization (Danil et al., 2022). Studies also reveal that good parenting, positive role models, and proper monitoring in schools can also play important roles in eradicating crime offences. This is why it is very important for communities, government, and non-governmental stakeholders to invest in improving neighbourhoods, facilities, services, and opportunities for education, which studies suggest can help eradicate and prevent criminal activities and victimization (UNODC, 2010).

2.3 Theoretical Framework to Risk Terrain Modelling

The importance of place in crime causation and crime prevention has been discussed over the years (Weisburd, 2012). Current environmental criminological theories of crimes such as rational choice theory, routine activity theory, and crime pattern theory give weight to the importance of location for understanding crime. As Ratcliffe (2010) has concluded, “together these three theories state that specific types of land uses and facilities generate crime as a result of the daily activities that are associated with them and the number and types of people they attract” (Ratcliffe, 2010). With increasing effectiveness, GIS and spatial analysis are being applied rigorously to examine the effect of “place” on crime. (Kennedy et al., 2016) state that one approach that has been developed to understand the environmental

context of crime and the role that sites, locations, or places in urban areas play in attracting criminal activities is risk terrain modelling.

Risk Terrain Modelling is an analytic technique based on the idea that crime offenders, crime victims, and crime targets operate in space and time and that the risk of a crime event occurring at a specific location is determined by a combination of social, cultural, economic, and physical environmental risk factors (Kennedy et al., 2011). Risk Terrain Modelling (RTM) is defined as an analytical method that analyses how events such as crime relate to other factors in the environment (Kennedy et al., 2011). It can also be defined as an assessment technique and a diagnostic method to identify the spatial attractions of criminal behaviour and environmental factors that are conducive to crime. The risk terrain modelling illustrates the spatial influences of crime that occur at a certain geographic surface, dictated by a combination of physical environments and cultural and social risk factors. The geographical surface or location is then calculated as an aggregation of spatial attributes. The RTM then combines geographical surfaces and common crimes likely to occur to yield risky terrain map. The risk terrain maps illustrate combined or averaged areas where the likelihood of crime occurring is high. The RTM is made up of three concepts which are as follows: risk, terrain, and modelling (Kennedy et al., 2011).

- Risk is defined as the incident's likelihood of happening. The incident or crime in this particular research can therefore be calculated with positive, negative, low, or high ordinal values. With the use of risk as a metric, it is possible to model how risk evolves spatially and temporally by accounting for the different stages of a crime event (Ohyama and Amemiya, 2018).

- Terrain is defined as the landscape attributes, which can be defined by low or high-lying areas on a map. Terrain is usually represented by raster maps. Raster maps can show landscapes on continuous surfaces.

- Modelling can be referred to as the patterning of the real world at certain places (Ohyama and Amemiya, 2018).

The purpose of RTM is to understand the social and physical contexts in which crime occur. The diagram below illustrates a theoretical framework to Risk Terrain Modelling.

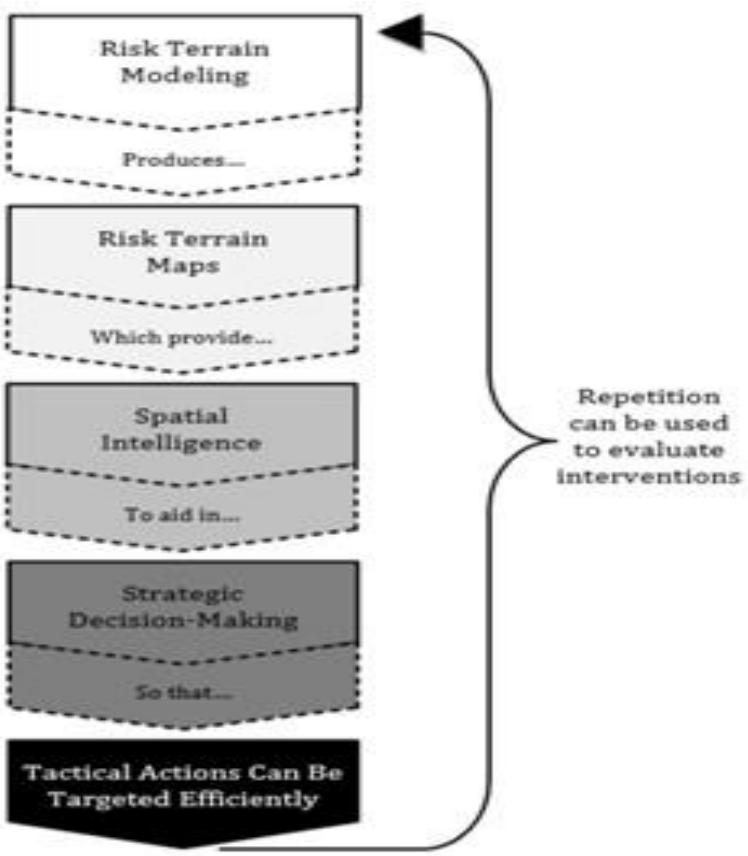

Figure 4: Theoretical Framework to Risk Terrain Modelling (Caplan et al., 2011)

2.4 Crime Risk Factors

This section explains work done or theoretical review of risk factors that are related to the selected types of crime in this study.

2.4.1 Risk Factor of Residential Burglaries

The term burglary can be described as illegal access or entry into a home or commercial building for purposes of stealing/ theft. Burglary is categorized into two types: residential and commercial (Vildosola et al., 2020). Studies suggest that burglaries are more driven by conducive environments that pave the way for burglaries to occur, such as surrounding areas, characteristics of premises,

immediate design and planning, and other lifestyle characteristics of certain locations (Zeng et al., 2021; Breetzke, 2012).

Residential and commercial burglaries are influenced by various factors, and there are various strategies in place to reduce and manage criminal incidents, as explained in this section. According to studies done on burglaries, there's a high level of criminal activity in homes that do not have access to quality security services, surveillance, or a disadvantaged background (Sheppard et al., 2022). Studies also show that these disadvantaged communities are homes to offenders, or offenders live near these communities (Ohyama & Amemiya, 2018). However, this section also unpacks some of the mitigation measures that can reduce burglary. Some of the aggravating and mitigating factors discussed are as follows: proximity to pawn shops, proximity to public transport, and time of day.

Studies suggest that burglars want to get rid of the good or valuable items stolen as soon as possible to avoid any detection by law enforcement authorities (Stevenson et al., 2001; Sheppard et al., 2022). Therefore, they tend to use pawn shops nearby to exchange any stolen goods for money. However, this is likely to happen in disadvantaged communities, where items with high value are more likely to be sold for less. Moreover, there is a high risk of increased burglary incidents in an area close to pawn shops (d'Este, 2020.). Public transport provides a smooth and easy way to connect transport. However, offenders are more likely to use certain locations that are closer to public transport, where they can connect. Proximity to public transport may also help offenders grow their criminal activities due to the transport accessibility.

Time is a very important factor for burglars. Research shows that burglars prefer or are more likely to break into a home when there is no one. Hence, it is more likely for burglaries to occur when a family is out at work, school, or vacation. In South Africa, the average workday ranges from 8 a.m. to 6 p.m. from Monday to Friday; thus, the period in between the time range paves the way for burglary to occur (Kennedy et al., 2011). It can be concluded that the proximity to police stations plays a positive role in reducing burglary. This particular factor has been shown to mitigate the risks of urban residential burglary. Most findings indicate that burglars consider the patterns of police activity when offending; thus, the increased presence of

authorities, the increased likelihood of authorities being present, and the increased ability of authorities to respond quickly can be considered mitigating factors resulting in a decrease of risk in a place (Kennedy et al., 2011).

2.4.1.1 Aggravating/Mitigating Risk Factors Based on Empirical Literature Review

To explicitly identify contextual factors that contribute to the risk of residential burglary in an area, an analyst can use a city-level unit of spatial analysis. It should be noted that crime correlates can be weighted. Based on prior empirical research, the following crime risk correlates were identified to be associated with urban residential burglary (Silva and Li, 2020).

Measures of Social Disorganization: Previous research has discovered that residences located in socially disadvantaged and disorganized areas experience high levels of crime due to low levels of socioeconomic status, low levels of collective efficacy and informal surveillance, high levels of ethnic heterogeneity, and high levels of residential mobility (He & Li, 2022). Also, residents in such places may not have the resources to protect their homes with adequate security measures (He & Li, 2022). Moreover, socially disadvantaged areas may have more offenders living within or in close proximity to the area, thereby increasing the overall level of risk in the place. It has also been discovered in research that offenders don't travel far to offend and do so based on a crime template derived from their daily routines, travelling paths, and overall awareness space (Bernasco, 2019). Lastly, some residents located at such areas may lack the appropriate security measures needed to prevent being victimized again, resulting in multiple victimizations. However, data must be up-to-date and recent if factors of social disorganization are to be incorporated within a risk-terrain model (Kennedy et al., 2011).

Proximity to Pawn Shops: Burglars are not only restricted to burgling a residence in a relatively quick fashion to avoid detection, but they also want to dispose of any stolen items as fast as possible. While majority of burglars may tend to seek out cash initially for immediate use, they may also find objects that can be easily taken and sold in exchange for money (Cheng et al., 2023). This can be true in some

impoverished areas, where objects that are of higher value or “hot products” tend to be at greater risk of being stolen as a result of their perceived value. Pawn shops, in particular those that have lax policies, are avenues for burglars to dispose of stolen goods in a swift and immediate manner (Dambe & Fombad, 2020). As a result of these effects, it is widely understood that proximity to a pawn shop will increase the risk of an area.

Proximity to Public Transportation: Public transit stations may place certain locations at greater risk than others since such connectors provide a way for offenders to access neighbourhoods more steadily while also providing a means for exit (Burdick-Will et al., 2019; Marquet et al., 2020). Offenders may be able to expand their crime template by making use of public transportation as a way to move in and out of nearby (or possibly at even greater distances) neighbourhoods (Caplan & Kennedy, 2011).

Land Use Type (Residential): Since residential burglary can only occur at residences, land use is mandatory to include as a risk correlate. Parcel data has been suggested to be particularly useful (Yue & Zhu, 2021).

Time of Day/Day of Week: Burglars have more tendencies to burgle a home when it is not occupied. Meanwhile, the occupation of a specific household can be dependent on the individual lifestyles of the occupants (Zhou et al., 2019). It is argued that specific time periods can be aggregated to identify risky times as a result of the general routine activities of most communities (Zhou et al., 2019). For example, an average workday in South Africa could range from 8 a.m. to 6 p.m. (accounting for possible travel time) from Monday to Friday; thus, the risk levels of an area as an aggregate would be higher during this time, causing households to be likely victimized due to a lack of guardianship (Steyn & Klopper, 2020; Mahfoud et al., 2021).

Proximity to Police Stations: This factor has shown to mitigate the risks of urban residential burglary. Most findings indicate that burglars consider the patterns of police activity when offending (Braga et al., 2019); thus, the increased presence of authorities, the increased likelihood of authorities being present, and the increased

ability of authorities to respond quickly can be considered mitigating factors resulting in a decrease of risk in a place.

2.4.1.2 Setting Effects

It should be noted that an appropriate area of study must be determined so as to distinguish between urban and suburban neighbourhoods. This process will surely affect the eventual framework, both theoretical and practical, during any analysis (Meško, 2020). This is especially true in any form of geographic analysis, as the different levels of spatial aggregation will require different data and techniques and will provide different outcomes (Meško, 2020). While a more specific level analysis could be conducted, such as a neighbourhood level, a high-risk area of a city may be identified based on the amalgamation of the crime correlates, creating an environmental setting conducive for residential burglary (Braga et al., 2019). Consequently, it may be possible to identify residences within such an area that could be at even greater risk solely based on individual characteristics of that home, such as security measures, points of entry, proximity to alleyways, etc. In addition, such neighbourhood-level analyses could apply specific risk terrains based on prior empirical evidence that acknowledges issues related to repeat victimization (including near-repeats, early repeats, and delayed repeats (Sameem & Sylwester, 2018; Aransiola & Ceccato, 2020).

Meanwhile, it should be noted that a broad application of RTK at the state-level in investigating the risk of urban residential burglary has its own limitations which include that when the study area is simply too large, there will be difficulty in identifying crime correlates that will produce meaningful information regarding a criminogenic environment (Wikström et al., 2017). Indeed, it can be argued that assessing a local-level problem like residential burglary through a state-level lens potentially results in the neglect of interactions and relationships that may be of importance (Wikström et al., 2017). It is therefore recommended that the most efficient and useful way to apply RTM to investigate the risk of urban residential burglary analysis based on the surrounding environmental context is at the city level where the identification of crime correlates and temporal features will produce information that is not only insightful but also practical (Caplan & Kennedy, 2011; Ohyama & Amemiya, 2018).

2.4.1.3 Temporal Differences

The concept of season, otherwise referred to as time periods, can inherently change the dynamics of an environment (Tonkin & Woodhams, 2017). For instance, selecting twelve-month or smaller time periods will account for seasonal fluctuations (such as winter months and summer months), commercial-retail times of the year (i.e., winter holidays), and work/school-related changes (i.e., summer holidays). It is mostly observed that the summer months result in increased guardianship in the form of children (possibly even a parent) staying home. At the same time, people also go on vacations at different times of the year, such as the summer and winter months, leaving their homes unattended (Tonkin & Woodhams, 2017).

2.4.2 Risk Factors of Street Robbery

It is believed that majority of street robberies take place in public places such as the street or in motor vehicles, and studies suggest that there are driving factors for such incidences to occur (Bernasco et al., 2017; Summers & Johnson, 2017). Factors that are believed to play major roles in aggravating and mitigating street robbery criminal offences are proximity to drug dealing areas, proximity to prostitution, proximity to public transport, proximity to bars, pubs, and exotic clubs, proximity to schools, and proximity to banks and cash points (Zhou et al., 2021; Zeng et al., 2021).

Most individuals that are involved in risky lifestyles could be involved in activities that are likely to be linked to disorderly/criminal behaviour. According to criminals, most people initially involved (or getting ready to be involved) in illegal activities are seen as perfect robbery targets because they are believed to be less likely to report crimes (Hayden, 2020). Moreover, robbers perceive police officers as less likely to intervene in robberies involving drug transactions (Zimmer, 1990). There are cases where the motive of a robbery is to acquire cash in exchange for drugs. The proximity to drug dealing areas is a strong correlate of street robberies, particularly when small-scale drug dealers (the possible robbery of both cash and drugs) and customers are targeted as victims (Zhou et al., 2021; Zeng et al., 2021). Criminals suggest that people who are after illegal sexual activities are in danger of being targeted by criminals because they are often in possession of money (Farley, 2006).

Also, it is believed that prostitutes rob their clients of their money because many prostitutes have drug addiction problems (Olofinbiyi et al., 2019). Therefore, streets that have high prostitution rates are more likely to experience high levels of robbery and criminal activities.

As mentioned above, criminals target areas close to public transports, they also use public transport; after committing robberies. These criminals also target public transport, such as trains, to commit robberies (Ceccato et al., 2022). It is also believed that proximity to nightlife attracts robbers because many people in these entertainment areas are too drunk to pay attention to their personal belongings. Studies and observation show that students are targeted by robbers; hence, areas in and around universities and high schools are prone to robbery and criminal activities.

One of the main factors in robberies is believed to be the proximity to banks and cash points. These are the service points where people can access their hard cash, thus makes them more vulnerable to robbery (Ceccato et al., 2022).

2.4.2.1 Aggravating/Mitigating Risk Factors Based on Empirical Literature Review

Most individuals that are involved in risky lifestyles could be involved in activities that are likely to be linked to disorderly/criminal behaviour (Gaind, 2020). According to criminals, most people initially involved (or getting ready to be involved) in illegal activities are seen as perfect robbery targets because they are believed to be less likely to report crimes (Graham et al., 2020). Moreover, robbers perceive police officers as less likely to intervene in robberies involving drug transactions (Hatten & Piza, 2022).

Proximity to Drug Dealing Areas: There are cases when the motive of a robbery is to acquire cash in exchange for drugs. The proximity to drug-dealing areas is a strong correlate of street robberies, particularly when small-scale drug dealers (the possible robbery of both cash and drugs) and customers are targeted as victims (Jasni et al., 2020).

Proximity to Prostitution Areas: According to criminals, it is often known that people seeking illegal sexual activities are ideal robbery targets because they will

be in possession of cash for the transactions and are expected to be more reluctant to report the crime incident (Olofinbiyi et al., 2019). In other words, since many prostitutes are addicted to drugs, it is assumed that high-prostitution areas may be a strong correlate for street robbery (Olofinbiyi et al., 2019).

Proximity to Public Transport: Particularly, criminals travel to public transport stations to commit crimes. Majority of the offenders often target victims waiting around isolated bus stops and train stations (Al-Ghiyadh et al., 2021). Furthermore, it is also observed that the vicinity of public transport areas has turned into crime attractors and crime generators with the constant flux of people, including the presence of other illegal activities such as illicit drug markets and ticket touts (Al-Ghiyadh et al., 2021).

Proximity to Bars, Pubs and Exotic Clubs: Majority of the offenders prefer to target their victims when they are drunk and thereby pay less attention to their personal safety (Omonya, 2020).

Proximity to Schools: Most offenders are used to attack students along the routes and short-cuts between main the university teaching sites and residence halls (Stalans et al., 2023).

Proximity to Banks and Cash Points: The proximity to cash points is expected to increase the likelihood of street robberies, as suitable targets will be cash-rich when leaving these sites. Most offenders are usually interested in locating targets that carry a substantial amount of money to acquire the dollar sum they need in just one offence (Ghannadpour & Zandiyeh, 2020).

Proximity to Post Offices: The practice of bag snatches from elderly people usually occurs around post offices (Zulyadi, 2020).

Proximity to Leisure and Fast-Food Outlets: It has been discovered that young, school-aged, people and young adults are usually targeted around leisure and fast-food outlets (Fe & Sanfelice, 2022).

2.4.2.2 Setting Effects

From the UN reports, it was discovered that crime levels are generally higher in urban environments compared to rural ones in all countries, with the highest levels of crimes taking place in cities experiencing rapid growth (Abubakar & Aina, 2019.). In the same way, victims of crimes in cities have a higher probability of being victimized in public spaces with respect to international victimization surveys

(Abubakar & Aina, 2019). Usually, street robbery's movement is primarily shaped by street grids in cities, and integrated streets attract more movement because of their ease of accessibility. In other words, robbers feel more comfortable in metropolitan areas where there is a camouflage of buildings and skyscrapers (Vasquez et al., 2020; Finlay et al., 2021; Cordeiro et al., 2020).

Times and Routines: Certain instances are found where most drunken people and migrant workers returning home after payday are mostly targeted at night (Devilly et al., 2019). Meanwhile, morning and evening rush hours have been observed to increase or decrease the likelihood of victimization depending on the level of natural guardianship placed in the specific city or neighbourhood (Erčulj, 2022).

Days and Routines: Usually, certain holidays such as New Year's Eve, Saint Patrick's Day, the Fourth of July, and Memorial Day may increase the odds of victimization because more suitable victims are present with valuables items to take (Lam, 2020). Moreover, there is likely consumption of alcohol by suitable targets on these holidays, which increases the vulnerability to victimization (Khurana et al., 2023). In the same way, days with sporting or other special events might have increased odds of robberies as a result of the availability of targets in public and the likely consumption of alcohol during the events. It has also been observed that the beginning and closing days of a school year and the holiday breaks can affect the likelihood of victimization depending on the availability of suitable and vulnerable targets in certain places (de Melo et al., 2018).

2.4.3 Operationalizing the Spatial Influence of Criminogenic Features

With the continuous utilization of spatial risk assessments and predictive analytics in the criminal justice community, operationalizing the spatial influence of crime factors on geographic units throughout a terrain is an important task that needs special consideration and tools (Berk, 2021). In particular, the use of GIS allows analysts to create visual narratives of how environmental settings become conducive to crime. GIS allows us to explore spatial influence, which refers to the way in which features of an environment affect places throughout the environment. Geographic information systems can produce maps that visually articulate these environmental contexts where certain crimes are more or less likely to occur as a result of the combined influence of one or more criminogenic features affecting the

same place. Through this process, criminal behaviour is modelled as less deterministic and more a function of a dynamic interaction that occurs at certain places (Dağlar & Argun, 2016).

An important conceptual tool for understanding relationships between places and crimes was provided (see Brantingham & Brantingham, 2017). They described the "environmental backcloth" that emerges from the confluence of routine activities and physical structures as overlaying areas. This backcloth is dynamic, but rather can be influenced by the forces of "crime attractors" and "crime generators" that contribute to the existence of crime hotspots. In the crime approach, *attractors* refer to the specific things that attract offenders to places in order to commit crime, while *generators* refer to the greater opportunities for crime that emerge from the increased volume of interaction occurring in these areas. Meanwhile, there are also some areas in most of the cities that push people away and some that contain few attractions. These areas are considered crime detractors (Brantingham & Brantingham, 2017).

In summary, operationalizing the spatial influence of crime risk factors addresses various theoretical and methodological issues concerning the use of GIS for crime forecasting and assessing place-based victimization risk (Kounadi et al., 2020). The most basic utility of this innovation is that it maximizes the validity of cartographic models and empirical measures used for statistical tests (Kounadi et al., 2020).

2.5 Predictive crime modelling

Predictive crime modelling can be referred to as various types of methods used to join factors such as social and physical to represent areas of crimes that are more likely to occur in certain geographic environments. Crime modelling was done differently in the past; researchers used to gather data on crime that has already occurred to map out spatial patterns present in the crime data gathered to predict criminal activities likely to occur (Egbert & Leese, 2021). However, with the birth of modern-day technology, crime forecasting can be done using GIS technology. Although technology has evolved, many studies still adopt a predictive crime modelling approach. This section explains predictive methods that are as follows: repeat victimization and hotspot analysis.

Several kinds of methods exist that seek to combine varying factors from the social and physical environment to model where certain crimes will likely tend to occur in the future. This is referred to as predictive crime modelling. The majority of forms of crime modelling in the past years have been retrospective in nature, meaning that they compile data on where crimes have already occurred in an effort simply to detect the spatial patterns that may exist within the data (Egbert & Leese, 2021). The use of GIS technology has really helped in predicting, or forecasting, where crime is more likely to occur. Despite the practice of predictive crime modelling still in its early stages, new developments in technology and models will continue to evolve to produce ever more accurate predictions (Kounadi et al., 2020; Bennett Moses & Chan, 2018).

Some lists of prevalent approaches to predictive crime modelling are discussed and evaluated in this section, namely: Hot Spot Analysis, Leading Indicators, Polygon Grid/Raster GIS Methods, and Repeat Victimization. Majority of software manufacturers have developed various programs for predictive crime modelling that utilize one or more of the methods discussed in this section.

2.5.1 Hotspot analysis

Crime hotspots are areas that have a greater than average number of criminal or disorder events or an area where people have a higher-than-average risk of victimization (Malleson & Andresen, 2016). Various types of data and studies require certain analytical models for data analysis purposes, and crime data is no exception to this. There are numerous models and methods used for crime studies, but the hotspot analytical method is commonly used for crime forecasting approaches (Bennett Moses & Chan, 2018; Kounadi et al., 2020; Shah et al., 2021). This method is better simplified as a tool that is used to assess whether high or low values of the number of crimes are clustered spatially and suggests that hotspots generated from past crimes are more significant in determining future crime hotspots, thus suggesting that the crime hotspot of the previous ten years is more likely to be the crime hotspot for today.

For instance, in 1995, a study conducted by Spelman (as cited by Bennett Moses & Chan, 2018) found that hot spots that were generated from incidents over a longer period had more predictive capability than ones generated from only one month of

incident data. He later discovered that hot spots generated within one year of incident data accurately predicted the locations of future incidents at a 90 percent accuracy level. This finding indicates that in some instances, hotspots tend to occur in the same locations over longer periods of time. This makes hotspot analysis limited simply because it is unable to explain why incidents occur in certain locations and was initially based on the assumption that what was true in the past will be true in the future (Bennett Moses & Chan, 2018). Although this method is widely used, its inability to explain why certain incidents happen in certain locations limits the hotspot analysis method.

2.5.2 Leading Indicators

The leading indicators method operates on the fact that certain precursors, which can indicate where a crime is likely to occur, are present. This can be explained by the fact that when a precursor occurs or is present (the independent variable) at a certain place, that place becomes more at risk of a particular type of crime (the dependent variable) occurring in the near future. A similar concept is repeat victimization which makes use of actual crime occurrence as a precursor to the same type of crime occurring at the same location in the near future (Bennett Moses & Chan, 2018). This approach to crime forecasting can be a complicated method to use because of the process involved in identifying the appropriate leading indicators for the respective crime types. Leading indicators need an end user to have good knowledge of statistics to determine which indicators have a significant impact on the dependent variable (Borowik et al., 2018).

2.5.3 Polygon Grid/Raster GIS Methods

Polygon grid and raster GIS methods apply the representations of factors found to have an effect on the occurrence of a certain type of crime. The next step is that the factors are converted to raster's and then combined using map algebra to give an overall risk surface for the type of crime being studied. Statistics knowledge is also needed for this approach to determine the correct combination of factors, as is knowledge of model building (Shafique et al., 2017).

2.5.4 Repeat Victimization

Repeat victimization can be described as either an individual crime victim or a location where a crime has initially occurred is now more likely to be the victim or

location of a subsequent incident within a few months of the original victimization. While the accuracy of the repeat victimization method varies significantly depending on the type of crime being studied, repeat victimization is known to be particularly accurate when applied to burglaries. Likewise, in 2001, Morgan (as cited by Groff & La Vigne, 2002) discovered in his study that residences close to repeat victims are also likely to be victimized. Morgan eventually termed these situations "near-repeats". The limitation of using the repeat victimization method is that it doesn't examine what factors influence the locations of the victimizations.

2.6 GIS in crime analysis

This section gives a review of how GIS has been applied for crime analysis elsewhere. The utilisation of GIS in the analysis of the spatial and temporal prevalence of crime has proven to be very valuable. It allowed different aspects of crime to be analysed with ease. The academic literature that has used GIS techniques to spatially analyse crime has been minimal. GIS and related technologies have turned crime mapping into a powerful decision-making tool for law enforcement agencies. However, GIS is beyond mapping, and increasingly so for crime analysis and law enforcement (Rummens et al., 2017).

Ahmadi et al. (2018) discussed that geospatial technologies are very useful for crime mapping at the district-level administrative division. They further explored that the Global Positioning System (GPS), Geographic Information System (GIS), and Remote Sensing are the most popular tools that are practically applicable in crime mapping. These technologies are not limited to mapping crimes; but they also play a vital role in predicting, analysing, and forecasting future crime-prone areas.

Mohammed and Baiee (2020) worked on how GIS is helpful in mapping and analysing crimes. Crime analysis nowadays is in fashion, and the role of GIS in Crime mapping and analysis has become a broad-spectrum term in most recent years, as it needs a lot of research on crime analysis and mapping. A survey-based analysis was conducted in which a crime survey and a victim survey were conducted in the study area. These surveys help criminologists and decision-makers to find out the emergence of criminal activities in an area and develop solutions to the problems.

According to Hussnain (2019), spatial geodatabases and analytical mapping are very important tools that are useful in analysing, preventing, and evaluating programmes for crime are increasingly recognized by police departments. For analytic mapping, law enforcement agencies need improved technological systems, high-graphic computerized GIS systems, and the availability of multiple sources of geographic data. GIS helps in identifying factors contributing to crime, and it works as a tool, thus allowing law enforcement agencies who are smarter to respond to a situation before it becomes complex and problematic. GIS can be used in law enforcement agencies in multiple ways, including crime analysis, strategy development, crime prediction, and decision-making on a real ground.

Aksoy (2017) worked on the relationship between space, place, and crime. They used hotspot analysis for liquor-related crime. They explained how the linkage between a place and a specific situation affects the crime ratio. They created a database (the Geo Archive) for storing crime, geocoding it, and performing hotspot analysis.

Malleson (2019) worked on the spatial distribution of crime to identify geographic crime distribution patterns. Crime analyses are used to achieve the required objectives. Multiple approaches are present for crime analysis, but GIS is the leading one. GIS software can create mapping dashboards that combine multiple data layers into useful information which can be displayed in the form of maps and web maps. Several factors are co-related to crime occurrence, the leading ones are demography, income, social conditions, education level, and land-use type, etc. These factors influence the offence rate and it's very important to include them while performing crime analysis.

According to Ratcliffe (2010), research on spatial crime mapping has great potential and will become a fundamental tool in law enforcement agencies. There are several approaches that are used for mapping crimes; the most popular ones are spatial-temporal mapping, and geographic profiling. These methodologies provide a full platform to run analysis for crime mapping more easily without huge effort. Crime justice's system and intelligence agencies need to adopt the technology for huge benefits from spatial technologies.

GIS is not just the process whereby a computer program is used to place electronic pins on static electronic maps; it is a tool with many capabilities for analysing and interacting with data. Ku and Leroy (2014) state that there is a need to give special attention to crime analysis. By using data analysis methods, that should be the start of the analysis of the crime dataset. The crime demonstrated the relationship between places where crime happens and when it happens. Crime hotspot detection is essential because people are located there; the intervention of crime-activated people affects crime. GIS is currently showing a significant development in research fields like crime analysis, and it includes a vast number of applications such as understanding crime distribution over space and time and modelling and predicting critical areas through pattern analysis.

A Geographic Information System (GIS), according to Talen and Shah (2007), is "an interactive mapping system that permits information layering to produce detailed descriptions of conditions and analyses of relationships among variables. A GIS is based on drawing different spatial distributions of data and overlaying them on one another to find interrelated points. Conditions, or filters, can be used in a GIS to refine searches at any level an analyst chooses." It can be used for analysing physical space, assigning perspective, and producing visual images of different styles of data in map layouts. Data displayed in the form of a map facilitates understanding of the significance of where, when, and by whom crimes are committed (Kedia, 2016). It also has the capability to change, visualize, query, and analyse tabular and geographic (spatial) data. The difference between manual pin maps and GIS is that GIS allows the analyst to examine the data beyond the geographic features, to join various features, to control the data and maps, and to perform statistical calculations. It allows the user to create anything from a simple point map to a three-dimensional visualization of spatial or temporal data (Smith & Paradis, 2020). There are many different brand names for GIS software packages, like ArcGIS®, MapInfo®, GeoMedia®, Atlas GIS®, and Maptitude®.

2.7 Spatial and temporal analysis: A view from a GIS perspective

Spatial analysis is a process in which you model problems geographically, derive results by computer processing, and then explore and examine those results. Several fundamental spatial analysis workflows form the heart of spatial analysis: spatial data

exploration, modelling with GIS tools, and spatial problem solving (Lawhead, 2019). Temporal statistical analysis enables you to examine and model the behaviour of a variable in a data set over time (e.g., to determine whether and how concentrations are changing over time). Spatial data analysis through Geographic Information Systems is becoming more popular in crime mapping and crime analysis. The aspect of time also plays a vital role in crime analysis. A crime is committed in a certain place, at a certain time, and this makes it easy to be analysed using GIS applications. The Geographic Information System as an analytical instrument is also used for pattern analysis or for the analysis of spatial crime distribution, and for researching spatial relations between crime and other demographic and socio-economic factors by using visual representations of spatial data. Spatial analysis allows you to solve complex location-oriented problems and better understand where and what is occurring in your world. It goes beyond mere mapping to let you study the characteristics of places and the relationships between them. Spatial analysis lends new perspectives to your decision-making.

Spatiotemporal models arise when data are collected across time as well as space and have at least one spatial and one temporal property. An event in a spatiotemporal dataset describes a spatial and temporal phenomenon that exists at a certain time t and location x. Spatiotemporal analyses have additional benefits over purely spatial or time-series analyses because they allow the investigator to simultaneously study the persistence of patterns over time and illuminate any unusual patterns. The analysis of spatiotemporal data requires that both temporal correlations and spatial correlations be taken into account. Assessing both the temporal and spatial dimensions of data adds significant complexity to the data analysis process for two major reasons: 1) continuous and discrete changes in the spatial and non-spatial properties of spatiotemporal objects; and 2) the influence of collocated neighbouring spatiotemporal objects on one another.

2.8 Crime prevention strategies

Crime is one of the most talked about and a major concern all over the world. Various countries have different strategies to fight these concerning issues, but the increasing rate has gained much recognition and is being politicised by politicians. This poses a challenge to solutions because politicians talk about crime in distorted

ways. Most politicians make the mistake of thinking that crime has a single cause; thus, they think simple solutions can address this challenge. Although politicians pose a threat to finding better solutions to combat crime, many researchers have been conducted in order to give direction as to what can be done to fight crime and some of the solutions offered, which are discussed below, are as follows: tougher sentences, the deployment of more quality police, and effective rehabilitation.

The crime rate has increased dramatically throughout the globe, and it is no surprise that some civil organisations, politicians, and civilians feel that offenders should be given harsher and tougher punishments, such as a death sentence (Cohen & Felson, 2010). The death sentence is not a new concept in South Africa; it was practiced throughout the apartheid era, and some feel the punishment should be reintroduced (Neumayer, 2008). It is not a secret that the South African police force is a mockery to the world; thus, some believe that the government must increase the number of police to fight crime. However, studies suggest that people are in need of a more functional police force than just adding numbers with no tangible results. Although these solutions might work for some criminal offences, it is believed that the increased number of police might not benefit victims of crimes such as rape, domestic violence, and child abuse, which take place in private. However, more police visibility will help combat crimes such as fraud, auto theft, and robberies (Macdonald, 2016).

It is believed that effective rehabilitation can help fight crime because research reveals that offenders are more likely to repeat the same offence when released back to communities prematurely without proper rehabilitation (Singh, 2016).

Naturally, crime does not disappear by itself. Police departments are on the duty of defending citizen's safety and taking precautions to minimize the risk of crime. It's long been common practice for the police to identify locations and times that are more liable to criminal activity. To reduce or eliminate crime, some actions, such as crime prevention methods, ought to be taken. Crime prevention can be signified as a set of ideas for combating incidents and includes the activities taken by individuals and groups, both public and private.

CHAPTER 3: METHODOLOGY

This chapter discusses how the research will be conducted. It unpacks research design, sampling techniques, tools that will be used to collect, organize, and record data, methods to be used for analysis of data, and data presentation.

3.1. Research Design

This research study adopted both quantitative and qualitative approaches in order to produce a more comprehensive study of the spatial and temporal distribution of crime in Thulamela Local Municipality. In crime analysis, both qualitative and quantitative techniques were used to analyse crime data in a more effective manner. Qualitative data and analytical techniques refer to non-numerical data analysis, which helps to discover underlying meanings and patterns. Quantitative analysis is based on data primarily in numerical or categorical format. Quantitative data is used primarily in the sense of statistical analysis. Crime analysis employs both qualitative and quantitative analysis of data and techniques, which depend on the analytical and practical needs. The research focused on both the process of the criminal activities and the outcomes. Selected interviews were conducted, well-structured questionnaires were administered, and measurable data was collected and analysed in this study.

3.1.1 Type of design adopted

A survey research design for crime was adopted for this study. The survey focused the types of crimes committed, the location, and the time when such crimes occurred. GIS software tools (ArcGIS) were used to collect measurable data and analyse it until the visualisation of the results.

3.1.2. Sampling techniques

This section seeks to explain the sampling techniques for the first stage which this research project adopted. There are two sampling units, primary and secondary sampling units, abbreviated as PSUs and SSUs, respectively. The random selection of households for this study was used across the nodal points in the Thulamela Local Municipality. The random selection made use of the 2011 Census and 2016 community survey data. Therefore, the data that was collected were compared with the targeted population to get a better picture of how criminal activities are spread

out within the nodal points of Thulamela Municipality. Thereafter, the collected data was weighted up to be representative of the target population which reflects the geographic spread of crime events.

3.1.3 Size and unit of analysis

This section indicates the areas that were selected from the population for further analysis. In other words, the unit of analysis is simply what or who can be studied; that is the major entity that you are analysing in your study. The unit of analysis in this study is geography (spatial and temporal).

3.1.4 Data collection

Data was collected from both primary and secondary sources. But the focus was mainly on secondary data. Primary data was collected from all three police stations which are within Thulamela Local Municipality, namely: Thohoyandou, Tshaulu and Tshilamba. The data collected included crime type, location, and time of occurrence. Secondary data such as population, administrative boundaries, satellite imagery map, municipal infrastructure services, and land-use and crime statistics data were sourced from Stats SA, Municipalities, and Esri SA.

Data collection tools that were utilized in the Victims of Crime Survey research are as follows: Voice recorder, Open Data Kit (ODK), and Collector for ArcGIS v10.3 software. The summary of the steps to conducting the victim of crime survey is shown in Figure 5 below.

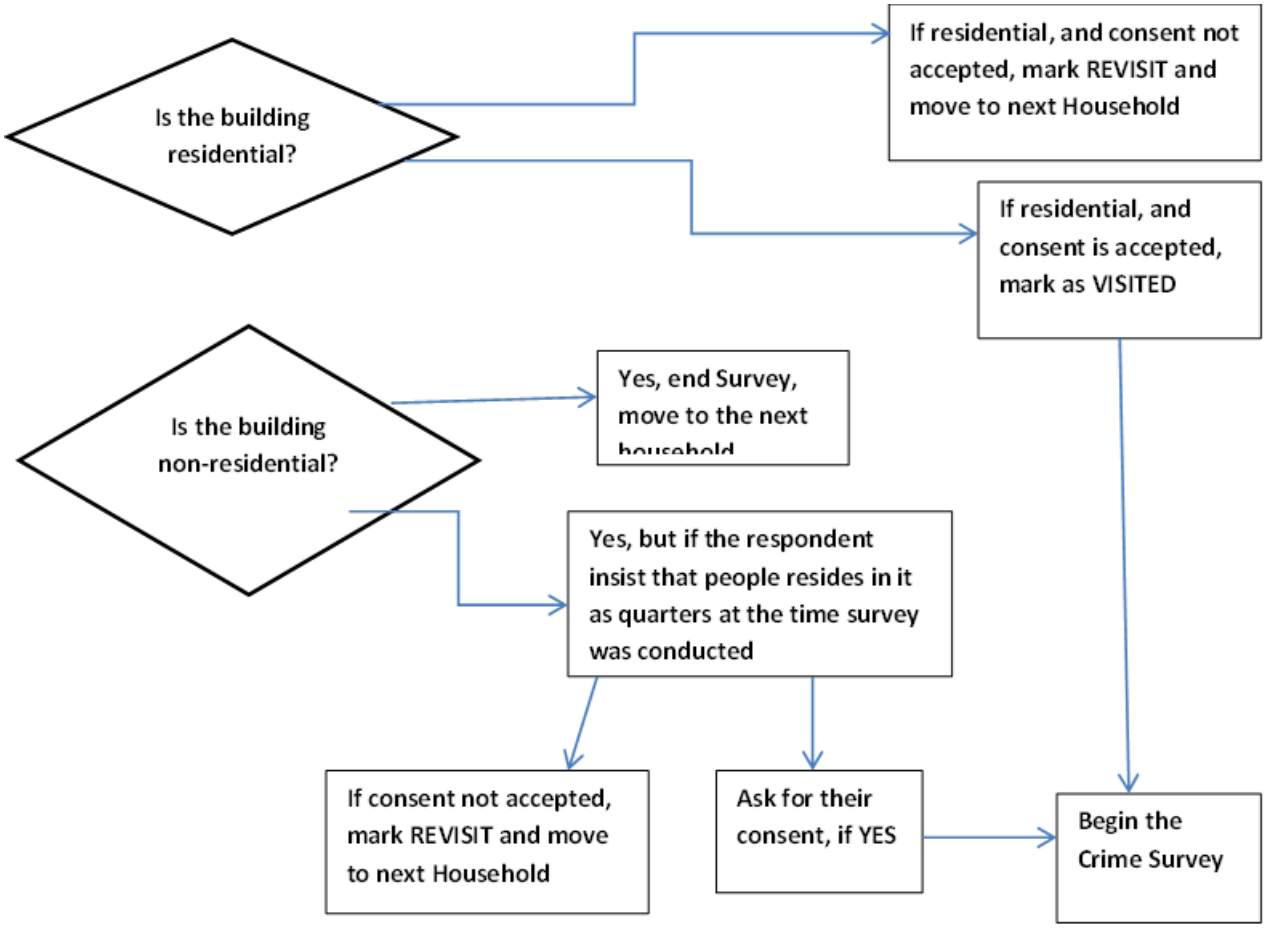

Figure 5: Steps used in conducting victims survey, spatial analysis in different locations and households visit surveys

3.2 Data Sources

The spatial datasets for this research included primary data such as geographic datasets (in vector and raster format), administrative data, land-use, settlement typology, road layers, and point-of-interest features. Secondary data included crime records at the police stations within Thulamela municipality, victims of crime survey data, and Census EA drawn from Stats SA 2011, and Community Survey 2016 crime data. The crime mapping employed quantitative data such as date, time, location, and type of crime to analyse these variables.

Table 1: Data sources

Datasets	Type of Formats	Source
Administrative boundaries	Shapefile as polygon features	ESRI
Crime incidence data	Shapefile as point features	SAPS, newly created
World map satellite imagery	Raster	Esri
Land-use	Shapefile as polygons	Newly created
River	Shapefile as polyline	Newly created
Settlement typology	Shapefile as polygons	Newly created
Place names	Shapefile as point features	Newly created
Open street maps	converted to shapefile	OSM
Commercial Infrastructural Services – such as Banks, bars/clubs/restaurants, beauty salons/barber shops, check-cashing stores, convenience stores, entertainment facilities, fast foods, gas stations, hotels/motels/inns, package stores, pawn shops, recreational facilities, strip malls, CCTV cameras.	Shapefile as point features	Newly created
EAs	Shapefiles as polygon features	SA Stats, drawn from 2001 Population Census conducted; some areas are newly created.

Municipal Infrastructural Services – such as apartment complexes, bus stops, cemeteries, parks and schools.	Shapefiles as point features	Newly created
Potential Offenders/Perpetrators of Crime - such as drug arrestees' home addresses, public drug complaint calls for service, parolees, released prisoners, probationers.	Shapefiles as point features	Newly created

3.3 Risk Terrain Modelling Technique (RTM)

Chapter 5 of the RTM manual explains the RTM methodology. Although data collection and manipulation are the most challenging aspects of the RTM model, the methodology outlined in the manual gives a clear direction on how to use RTM (Kennedy et al., 2011).

3.4 Data Analysis

Data was analysed for various argumentations, i.e., spatial distribution of crimes, temporal trends, and identification of hotspots. For this purpose, the local municipality map was scanned and digitized in ArcMap along with the demarcated police station boundaries. After the creation of a geodatabase, a point map "crimes" was created, and the spatial distribution of different crimes were marked with the help of a point map. The different attributes of crime was recorded in the attribute table of a point map "crimes," i.e., location, time, date, type, etc.

GIS techniques was applied to align with the specific objectives of the study as follows:

- **To determine the crime hotspots and spatial distribution of crime prevalence such as house breaking, pick pocketing, murder and public violence in Thulamela Municipality**

  The following mapping cluster tools were used for this specific objective: spatial analyst tools, spatial statistics tools, and hotspot analysis (gertis-ord-

gi). The Hotspot Analysis tool was used to calculate the Gertis-Ord GI statistic for each feature in a dataset and identifies statistically significant spatial clusters of high values (hotspots) and low values (coldspots). It automatically aggregates crime data; identifies an appropriate scale of analysis; and corrects for both multi-testing and spatial dependence.

In determining the spatial distribution of crime prevalence, analysing pattern toolsets such as average Nearest Neighbour, High/Low Clustering, Incremental Spatial Autocorrelation, Multi-Distance Spatial Cluster Analysis and Spatial Autocorrelation were used. The analysing patterns tools provide statistics that quantify broad spatial patterns. These tools answer questions such as, “Are the features in the dataset, or the values associated with the features in the dataset, spatially clustered?” and “Is the clustering becoming more or less intense over time?”

- **To analyse temporal trends in crime prevalence from 2010-2019**
  Space-time cluster analysis tools were used to analyse temporal trends in crime prevalence in Thulamela Local Municipality. Temporal data such as date and time information of geographical locations assisted in tracking real-time and previously documented crimes. Data has both a spatial and a temporal context: everything happens someplace and occurs at some point in time. Several tools, including hot spot analysis, cluster and outlier analysis, emerging hot spot analysis, and grouping analysis were used to analyze temporal trends of crime. The ArcGIS tracking analyst extension accepts stored temporal or fixed-time data as well as real-time data from several sources. Therefore, temporal data were added as a layer in ArcMap. This data includes time and date information for geographic locations which allow one to track real-time and previously documented observations.

- **To identify factors that influence crime prevalence and crime risks and operationalize crime risk factors**
  The Risk Terrain Modelling Tool was used. This objective was to identify crime risk factors and unpack the operationalization of risk factors such as

proximity to public transport (Bus ranks), banks, bars, and other factors in point, line, and polygon form.

Table 2: Steps for Risk Terrain Modelling for creating risk factors using map layers

Step to be followed	Description
Step 1: Select crime type	Choose the type of crime that will be studied.
Step 2: Choose a study area.	The study area for RTM can be any size, but it is important to ensure that the data are available for the extent chosen and that the data are detailed enough to produce a meaningful representation of the potential risk factors.
Step 3: Choose a time period	The time period that the RTM will represent depends on the intended purpose of the final model. If the time period of interest is a single month, utilizing data from that month of the previous year is much more representative than data from every month of the previous year.
Step 4: Create a basemap.	The minimum base map data needed is a polygon of the area of interest. Other base map data may be included for aesthetic and orientation purposes.
Step 5: Identify risk factors	Compile an as comprehensive as possible list using personal knowledge, empirical analysis, and literature review.
Step 6: Choose risk factors to include in final model.	Here the comprehensive list of potential risk factors is reduced based on

	relevance to the study at hand and availability of quality data to represent the factor. More risk factors do not necessarily produce a better model.
Step 7: Develop spatial representation of risk factors	Each risk factor is converted to raster format in a way that "reasonably and meaningfully represents the influence of the risk factor" (Caplan & Kennedy, 2010, p. 86). The cell values for each raster are standardized according to a common index.
Step 8: Weight risk map layers.	If the assigned values according to the common index do not sufficiently serve as the weight for each risk map layer, logical regression analysis may be used to determine the appropriate weights.
Step 9: Combine risk layers.	Compilation of the risk map layers is accomplished using the raster calculator tool.
Step 10: Finalize risk terrain output	The final composite map is symbolized to effectively communicate the overall risk findings. Statistical testing may be done to determine if any statistically significant clusters exist.

Source: Kennedy et al. (2011)

The data analysis section explores the methods used to analyse the data in this research project to apply Risk Terrain Modelling in ArcGIS

3.4.1 Risk Factors' Operationalization

This section seeks to unpack the operationalization of the risk factors such as proximity to public transport, banks, and other factors mentioned above in a point, line, and polygon form (Goetz, 2012). This is shown by the figure above, which shows the general workflow of the RTM modelling tool. Risk factors are

operationalized with a vector grid, and they are as follows: pre-processed feature classes of the risk factors are operationalized with risk factors such as burglary (Goetz, 2012). Different buffers, such as highway exits, schools, and proximity to police, are created and categorised into different classes. This is used for statistical tests on correlation (Valasik et al., 2019).

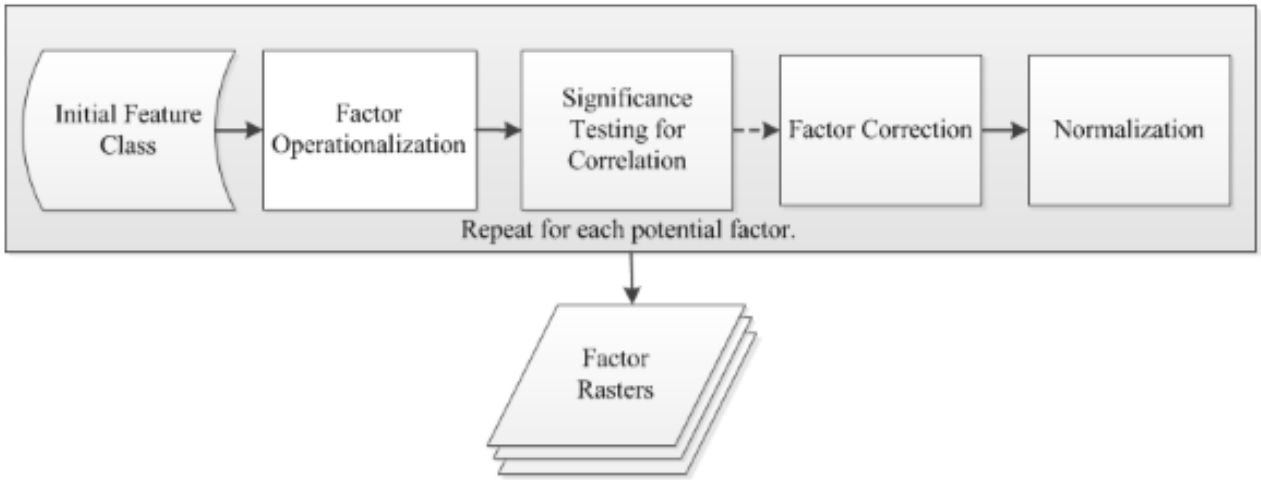

Figure 6: Risk terrain model factor operationalization showing feature classification and response factors.

Statistics provide a set of quantitative methods for characterizing a dataset or comparing one dataset to another, and a data sample is compared to a theoretical or a known distribution of data values. Spatial statistics do the same; however, they consider the spatial relationships among locations and (measured) phenomena occurring at those locations. Spatial statistics allow one to supplement the subjective perspective of your data with concrete numbers and statistics. Statistics help with enhancing communication, fostering consensus, facilitating problem-solving through analysis, promoting decision-making, and providing mechanisms for evaluating the impacts of those decisions.

A spatial pattern may lead to questions about the possible processes that create the pattern. Most spatial phenomena exhibit some type of pattern that is probably influenced by some other factor. Spatial statistics are the application of tools and methods that use space and spatial relationships (such as distance, area, length,

orientation, centrality, coincidence, connectivity, and orientation) directly in their mathematical computations. Spatial statistics allow you to do the following tasks:

- Minimize the subjectivity inherent in human visual interpretation of maps and spatial data.
- Identify and quantify patterns and trends in data that may not be revealed in visual analysis.
- Answer questions more confidently and make important decisions using more than simple visual analysis.

CHAPTER 4: RESULTS

4.1 Spatial distribution analysis and its tools

Crime in the areas was happening all over the study area; determining the spatial distribution of the crime prevalence helped understand where clusters are located. This analysis was conducted to discern and gain insights into the spatial distribution patterns within the dataset. Cold spots represent regions where crime incidents occurred at a significantly lower rate than expected based on a random spatial distribution. In contrast, hot spots denote areas with a notably higher concentration of crime incidents, indicating areas of heightened risk or vulnerability. The "not significant points" on the other hand, represent areas where crime incidents did not display a significant spatial clustering pattern, suggesting that crime rates in these regions are relatively stable or consistent. Analyzing the interplay between these three categories of spatial patterns provides a comprehensive understanding of crime dynamics in the area.

Using the ArcGIS Pro software, there are two hot spot analysis tools: the Hot Spot Analysis (Getis-Ord Gi*) and the Optimized Hot Spot Analysis. Both utilize the Hot Spot Analysis (Getis-Ord Gi*) tool, but Getis & Ord, (1992) explained that the Optimized Hot Spot Analysis tool goes a step further by examining the data to identify the most suitable parameters. Both tools provide z-scores and p-values, which serve as indicators of spatial clustering for features with either high or low values. For a hotspot to be statistically significant, it must exhibit a high value and be situated in an area where other features also have high values.

4.1.1 Hot Spot Analysis

In Figure 7, the areas situated east of Tshaulu on the map are classified as hot spots. These are regions where there is a significant amount of crime happening, and the crime data is not under random spatial distribution. There are several cold spots distributed across the area, which means that the crime in the area is not congested in one area but rather spread across the area. The results from this study indicated 90, 95, and 99% confidence in the spatial analysis of crime hotspots in Tshaulu from 2015 to 2019. Similarly, cold-spots areas showed high confidence in

the Tshaulu area, ranging from 90 to 99% (Figure 7). The results showed a convergence in crime from one area to another, with a high risk of crime occurrence at Tshaulu central village (Figure 7). These results exhibited significant differences since the confidence values were very high.

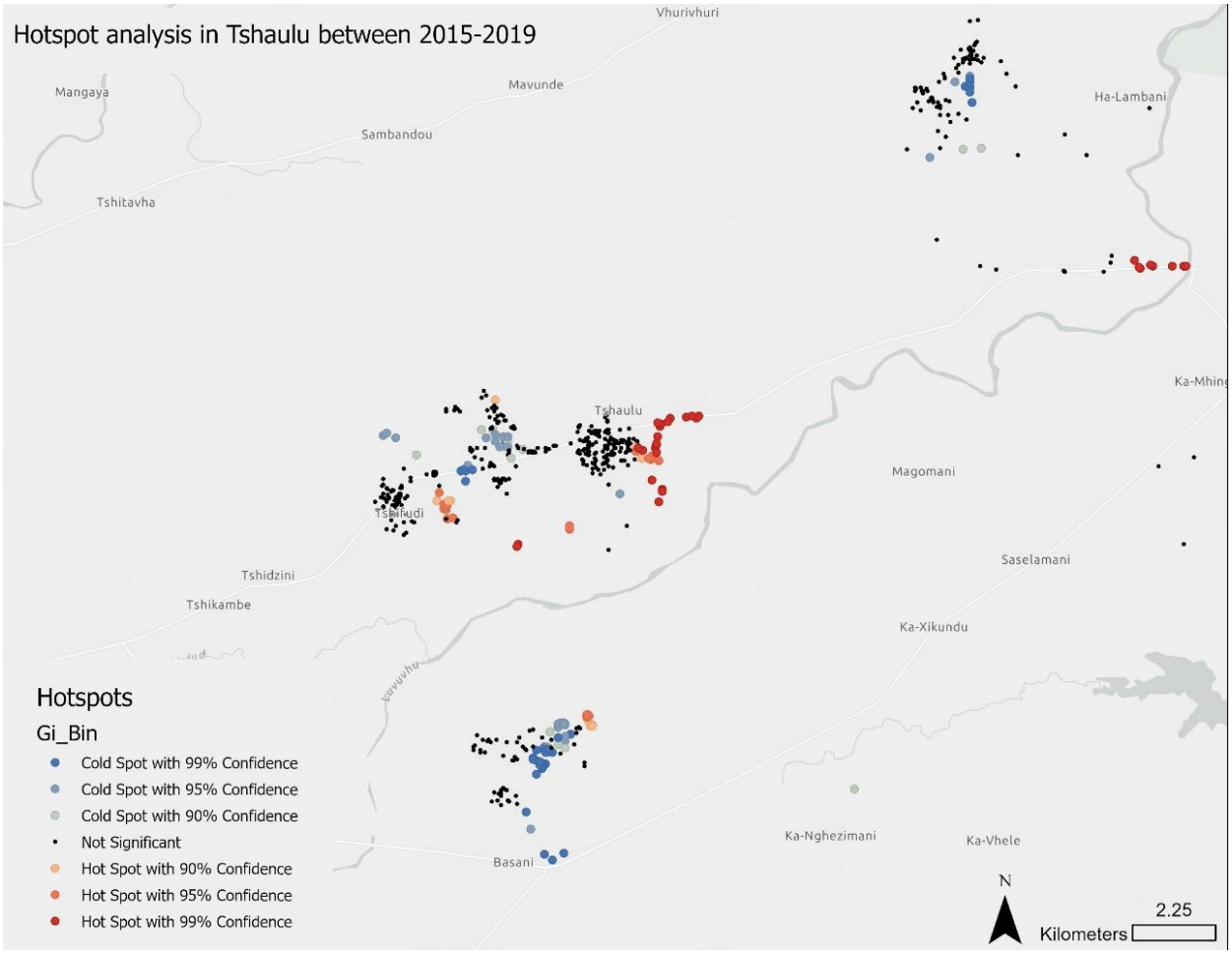

Figure 7: Hotspot analysis at Tshaulu between 2015-2019 with confidence values under random spatial distribution

In Figure 8, cold spots can be spotted in various areas on the map in Thohoyandou. This suggests that the areas where the occurrence of a particular phenomenon or event is significantly lower than expected based on random spatial distribution. These areas represented regions where the phenomenon is less prevalent or where there may be factors suppressing its occurrence. The area southeast of Tshaulu and Tshifudi has multiple hot spots, these areas are characterized by an increased risk or intensity of the phenomenon/crime (Figure 8). The confidence values for the Thohoyandou area were very high, resembling significant differences and an

increased rate of crime occurrence (Figure 8). A significant increase was observed from 2015-2019 in terms of crime prevalence.

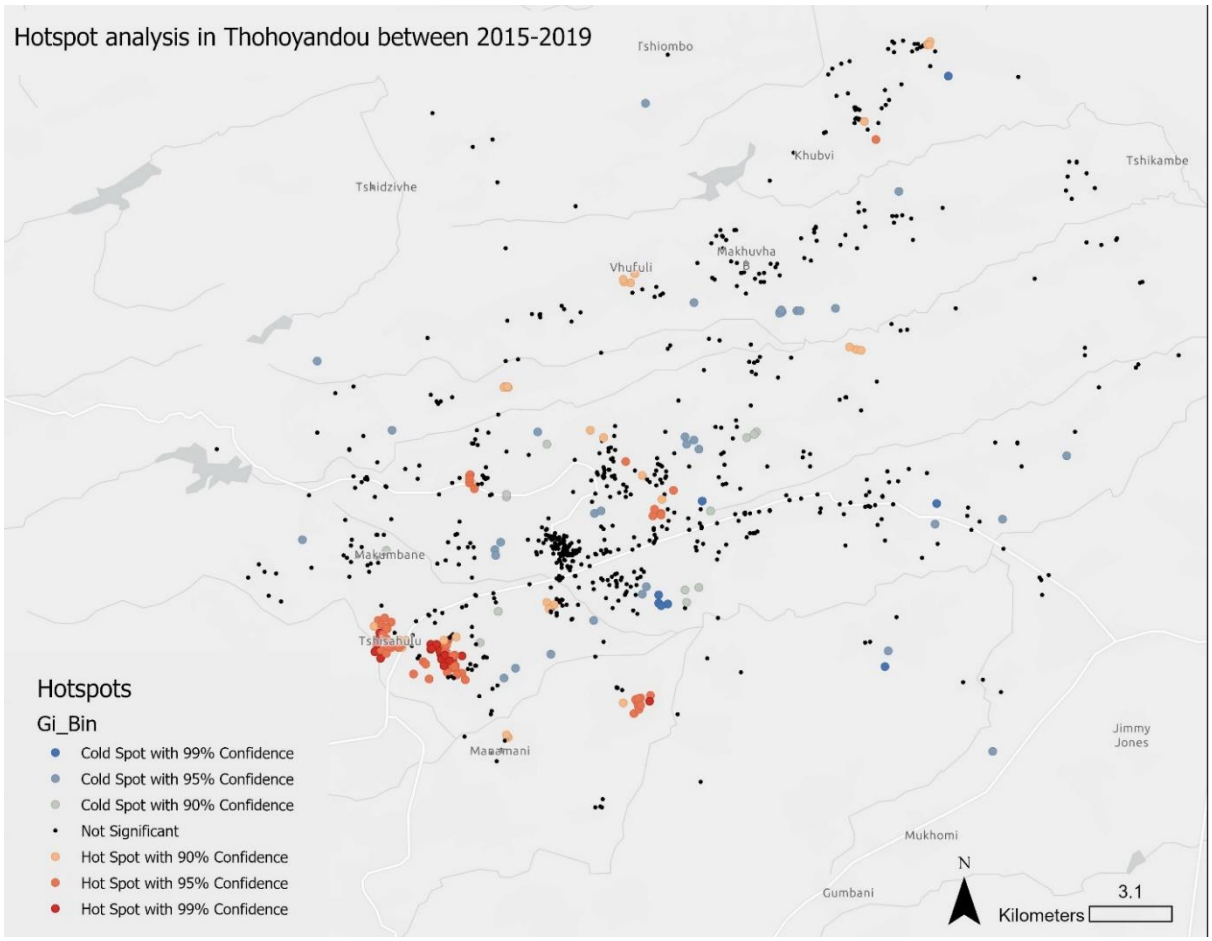

Figure 8: Hotspot analysis at Thohoyandou between 2015-2019 with confidence values under random spatial distribution

The hotspot analysis of crime incidents in the Mutale area indicated a high number of cold spots, suggesting that the area is not prone to a high rate of crimes (Figure 9). Although villages such as Manamani and Makumbane resembled a high confidence degree of 90-95%, this suggests that crime prevalence in the area is fixed at certain points (Figure 9). The area has more cold spots than the previous two, Tshaulu and Thohoyandou. The hot spots are not concentrated in one area or section but are distributed unevenly across the area, with certain outliers visible (Figure 9). From the results, I have observed that crime remained constant from 2015-2019 with significant changes in 2019 where more hotspots were identified.

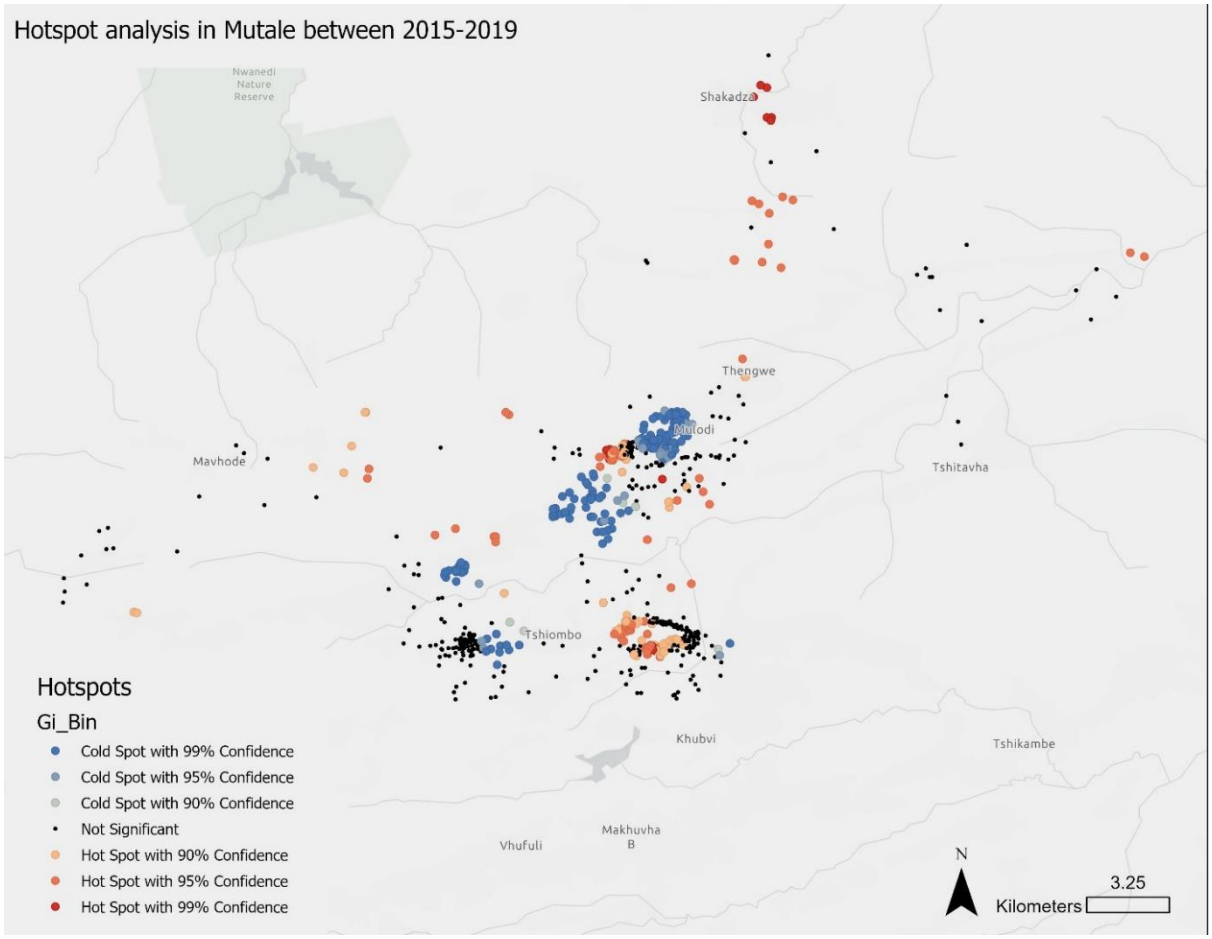

Figure 9: Hotspot analysis at Mutale between 2015-2019 with confidence values under random spatial distribution

4.1.2 Optimised hotspot analysis

In the crime analysis of Tshaulu, we applied Optimized Hot Spot Analysis to scrutinize the spatial distribution of criminal incidents over the past five years. By optimizing the analysis parameters to fit the characteristics of this specific area, we identified statistically significant hot spots where crime was concentrated (Figure 10). The results unveiled a notable hot spot in the centre of the area. This optimization process allowed us to fine-tune the spatial scale and neighbourhood boundaries to accurately capture these crime clusters. From the confidence degrees, I have observed significant differences from 2015-2019, with a high confidence percentage falling in Tshaulu village (Figure 10).

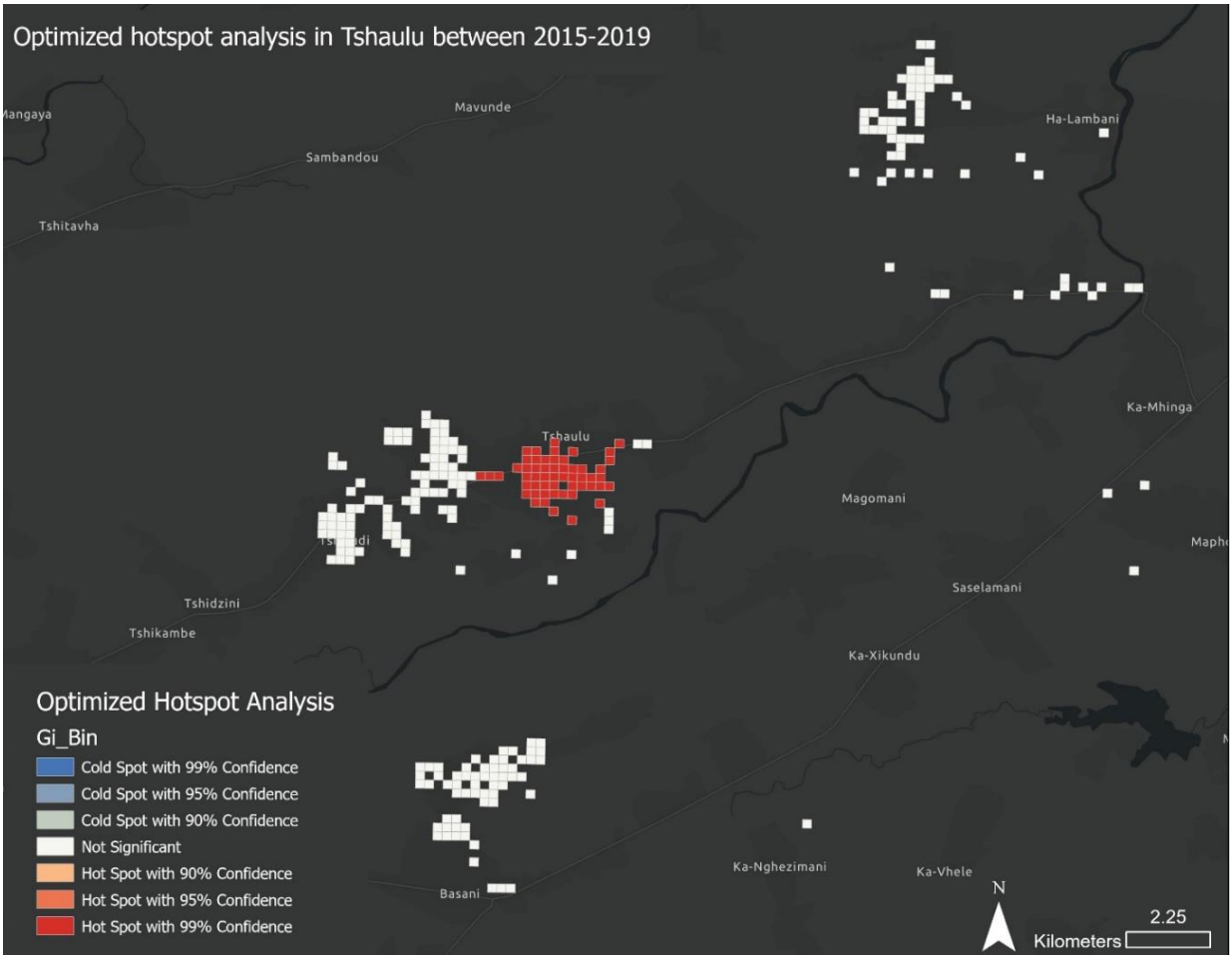

Figure 10: Tshaulu optimized hotspot analysis between 2015–2019

The Optimized Hot Spot Analysis tool enhances the accuracy of identifying clusters by optimizing parameters; it is also better equipped to discriminate between true clusters and random patterns. This means that the identified hot spots and cold spots are more likely to be meaningful and statistically significant at Thohoyandou. Optimized Hot Spot Analysis represents a refined approach to conventional Hot Spot Analysis (Getis-Ord Gi*). As *Figure 11* shows, there is a change in the number of hot spots in the area as compared to the Hot Spot Analysis. The results further indicated that more crime prevalence occurred at Thohoyandou CBD compared to other neighbouring villages. This is attested by the confidence percentage, which was very high in Thohoyandou CBD, ranging from 90-99% and also indicating significant differences from 2015-2019 in terms of crime occurrence (Figure 11).

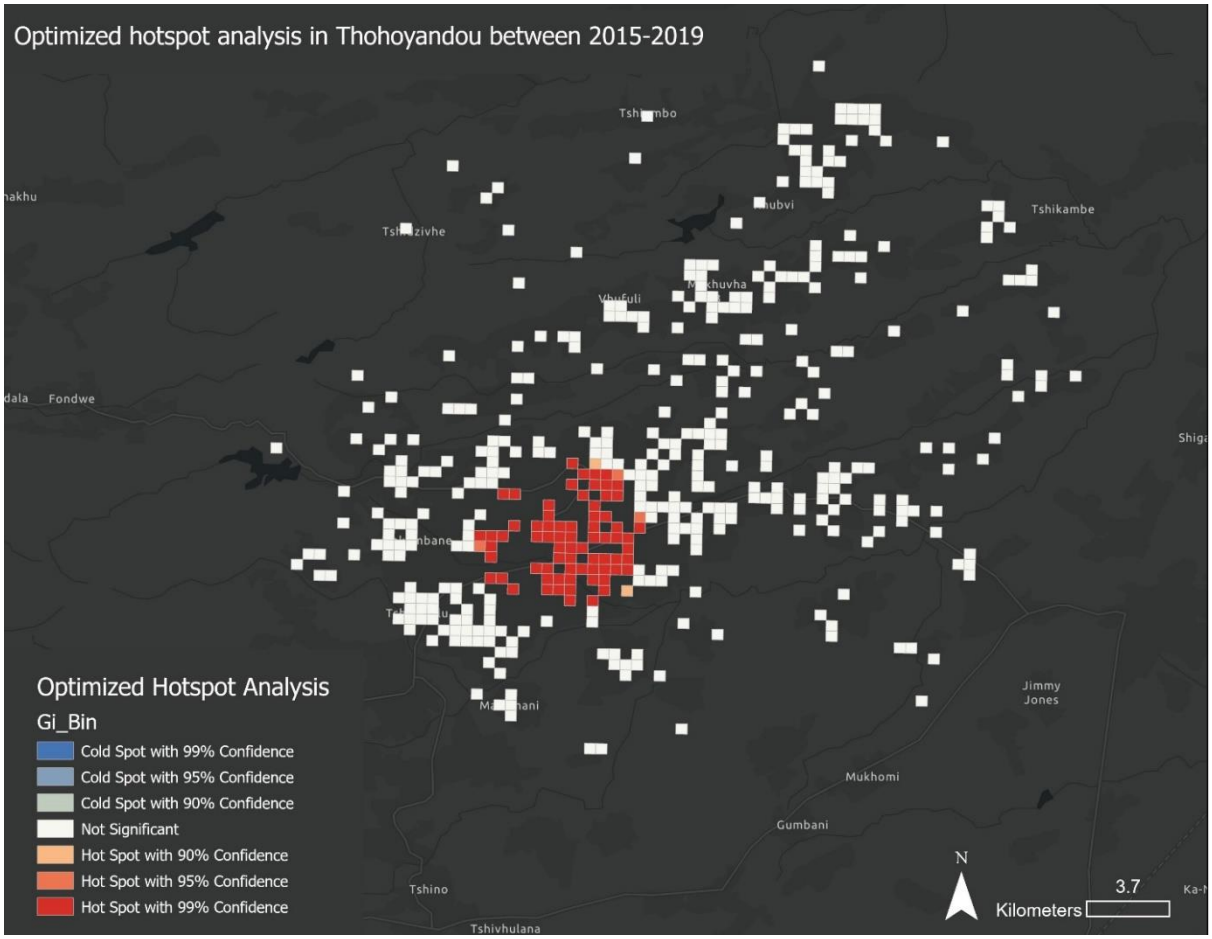

Figure 11: Thohoyandou optimized hotspot analysis between 2015–2019

Similar to other optimised hotspot analyses, the results from Mutale Village indicated a spatial distribution of crime occurrences from 2015 to 2019 (Figure 12). The crime prevalence increased from 2015 to 2019 with an increase in residential areas. Cold spots were more abundant than hotspots with a similar trend to Thohoyandou, where much of the crime occurred because of economic activities (Figure 12). Through the optimization process, we identified statistically significant hot spots in two areas (Khubvi and Thengwe). These findings offered critical insights into localized crime trends.

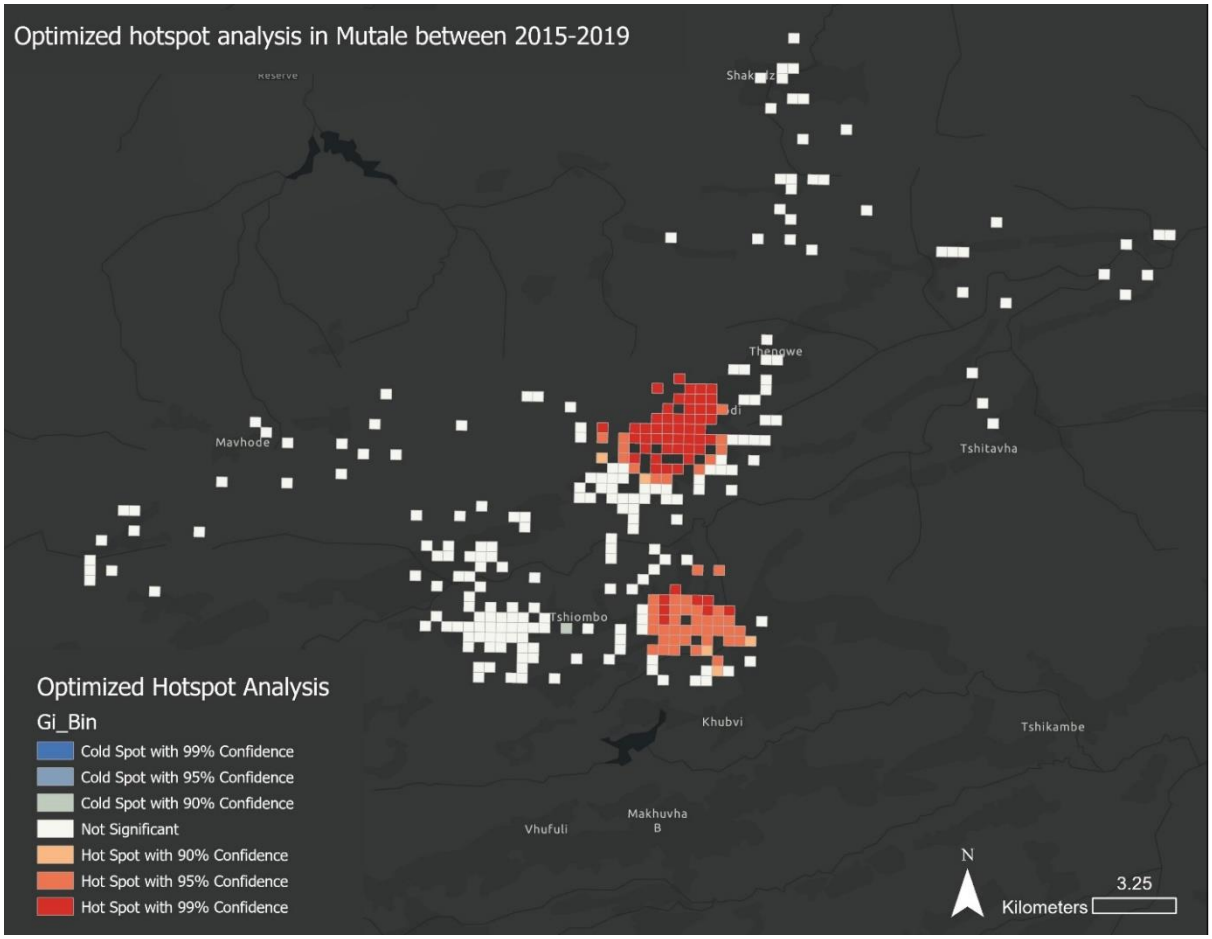

Figure 12: Thohoyandou optimized hotspot analysis between 2015–2019

4.2 Temporal trends of crimes between 2015-2019 – Directional Distribution (Standard Deviational Ellipse)

I used a directional distribution tool to identify temporal trends in the crime data. The ellipse indicated a directional trend that is based on the orientation of the sample points. When the underlying spatial pattern of features is concentrated towards the centre with fewer features towards the periphery, one standard deviational ellipse polygon covers approximately 63 percent of the features. As such, choosing two standard deviations and including more of the crime incident points results in a larger ellipse with a similar directional trend as the other ellipse for one standard deviation and covers more than 90% of the crime incident points. The Average Nearest Neighbour tool only looks at feature locations to determine if they are clustered or dispersed. To determine if there is clustering in the attribute values at those locations, I ran the Spatial Autocorrelation (Moran's I) tool.

4.2.1 Directional distribution ellipsoids

The directional distribution ellipsoid analysis was conducted using ArcGIS Pro. This analysis provides insights into the directional trends and spatial dispersion of crime data.

In our crime analysis conducted in Tshaulu (shown in *Figure 13*) over the years 2015 to 2019, Directional Distribution Ellipsoid Analysis was instrumental in unravelling temporal trends in crime occurrences. The directional distribution ellipsoid created for this rural area depicted a consistent pattern in crime directionality. The axis consistently pointed towards the northeast and southwest, indicating that the primary direction of criminal incidents remained stable throughout the study period (Figure 13). Additionally, the ellipsoid's slight fluctuations year by year provided insights into the slight changes in the dispersion of crime in the landscape. The ellipsoids have a certain consistency about them, hinting at more consistent criminal activity in the area. The results from the present study indicate that the crime incidences were prevalent in the southwest region of Thulamela municipality, with high incidences being observed in Tshaulu and Basani villages (Figure 13). Although the ellipse incidences overlapped even in areas such as Mhinga village, this was not significant since crime was low in the latter areas (Figure 13).

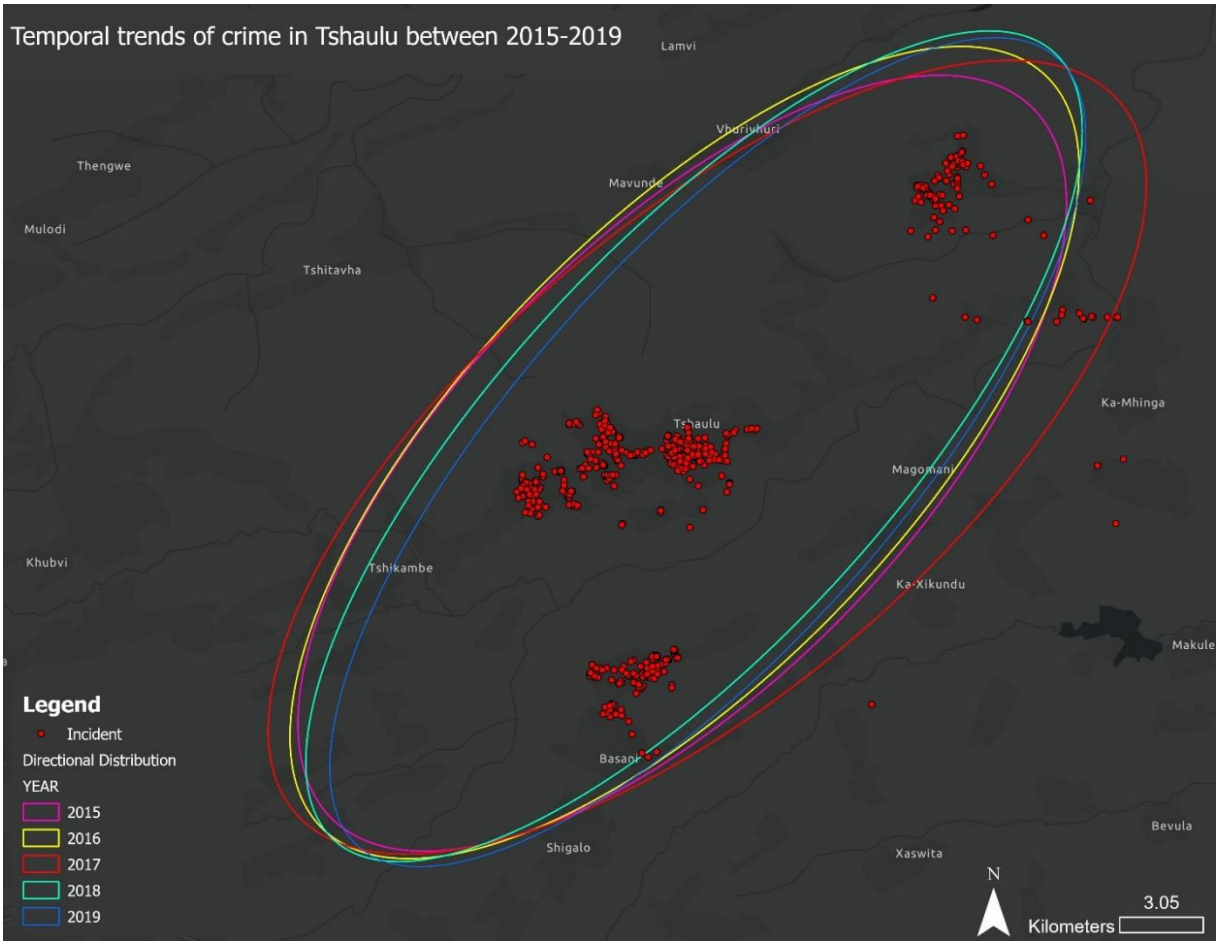

Figure 13: Directional distribution of crime per year in Tshaulu

In the crime analysis of Thohoyandou spanning from 2015 to 2019, I utilized Directional Distribution Ellipsoid Analysis in ArcGIS Pro to gain insights into the temporal trends and patterns of criminal incidents. The directional distribution ellipsoid created for this area visually represents the changing dynamics of crime over the five-year period. By examining the axis of the ellipsoid shown in *Figure 14*, I was able to discern significant temporal patterns. For instance, the axis indicated that the primary direction of crime occurrence shifted slightly southwest and northeast over the years, suggesting changes in the spatial focus of criminal activity. Furthermore, the size of the ellipsoid provided insights into the overall dispersion of crime incidents (Figure 14). The crime in 2015, which is represented by the Purple coloured ellipsoid, was spread across the area, hence a larger ellipsoid, but as the years went by, the crime became concentrated in the same area, and the ellipsoids got get smaller. There was also a change in the areas where the crime was happening, as shown by the direction of the axis of the ellipsoids (Figure 14). It is very clear that Khubvi, Vhufuli, Makhuvha,

Tshikambe, Tshiombo Mananamani, and other nearby villages resembled high crime incidences (Figure 14).

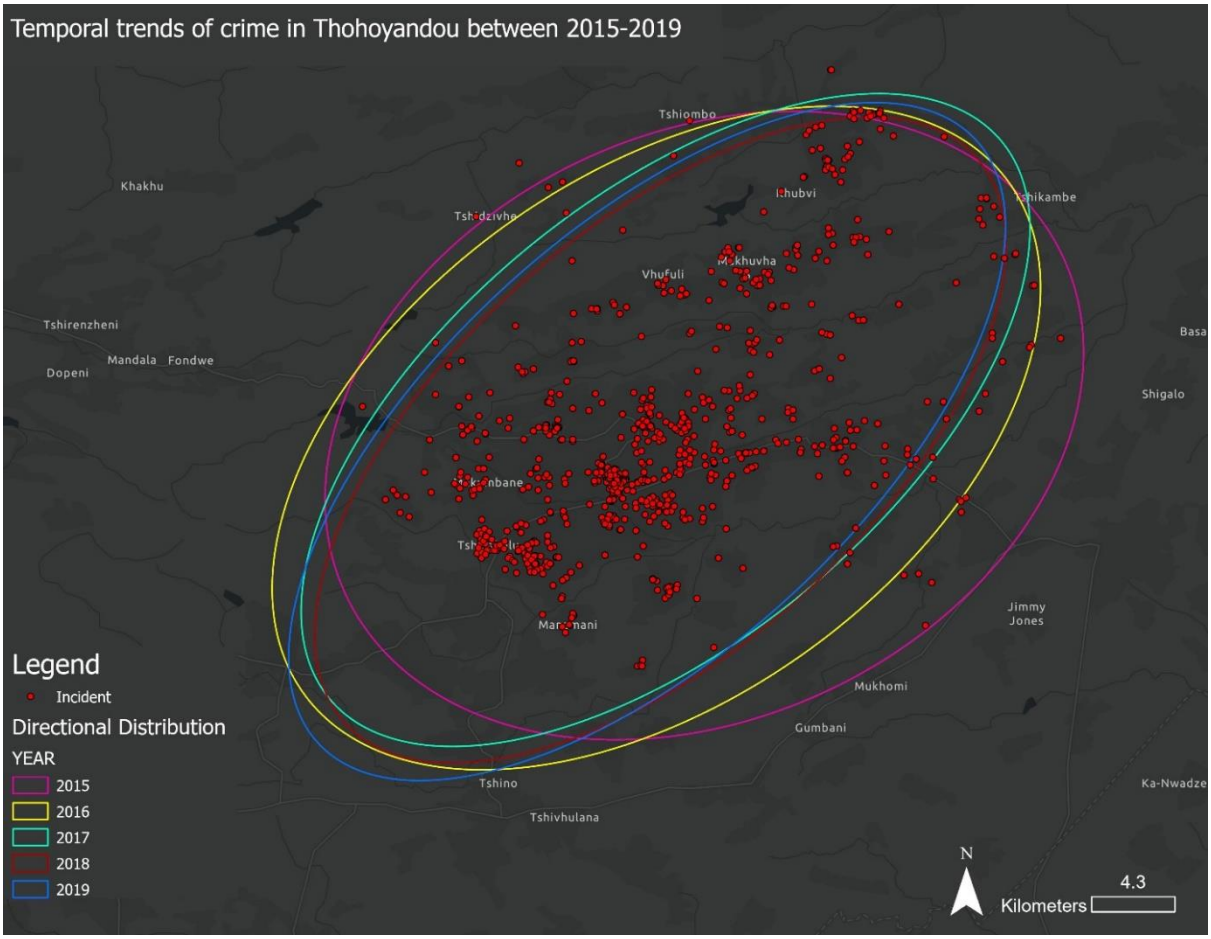

Figure 14: Directional distribution of crime per year in Thohoyandou

In this map (Figure 15), the ellipsoid represents the directional distribution of crime in the area per year. The size of the ellipsoid indicates the geographical distribution or spatial dispersion. For example, from Figure 15, year 2015 (purple), the crime is not spread across the Mutale area as compared to year 2017 (green), where the crime is spread across the area, hence the ellipsoid is larger than the purple one. By examining the directional distribution of ellipsoids for each year within the study period, I observed that the orientation and size of the ellipsoid evolved over time. This indicates changes in the spatial patterns of crime in the area (Figure 15). Various areas in the Mutale area showed a positive incident correlation from 2015 to 2019, with significant changes in specific areas such as Mulodi, Thengwe, and Tshiombo having high crime occurrences (Figure 15).

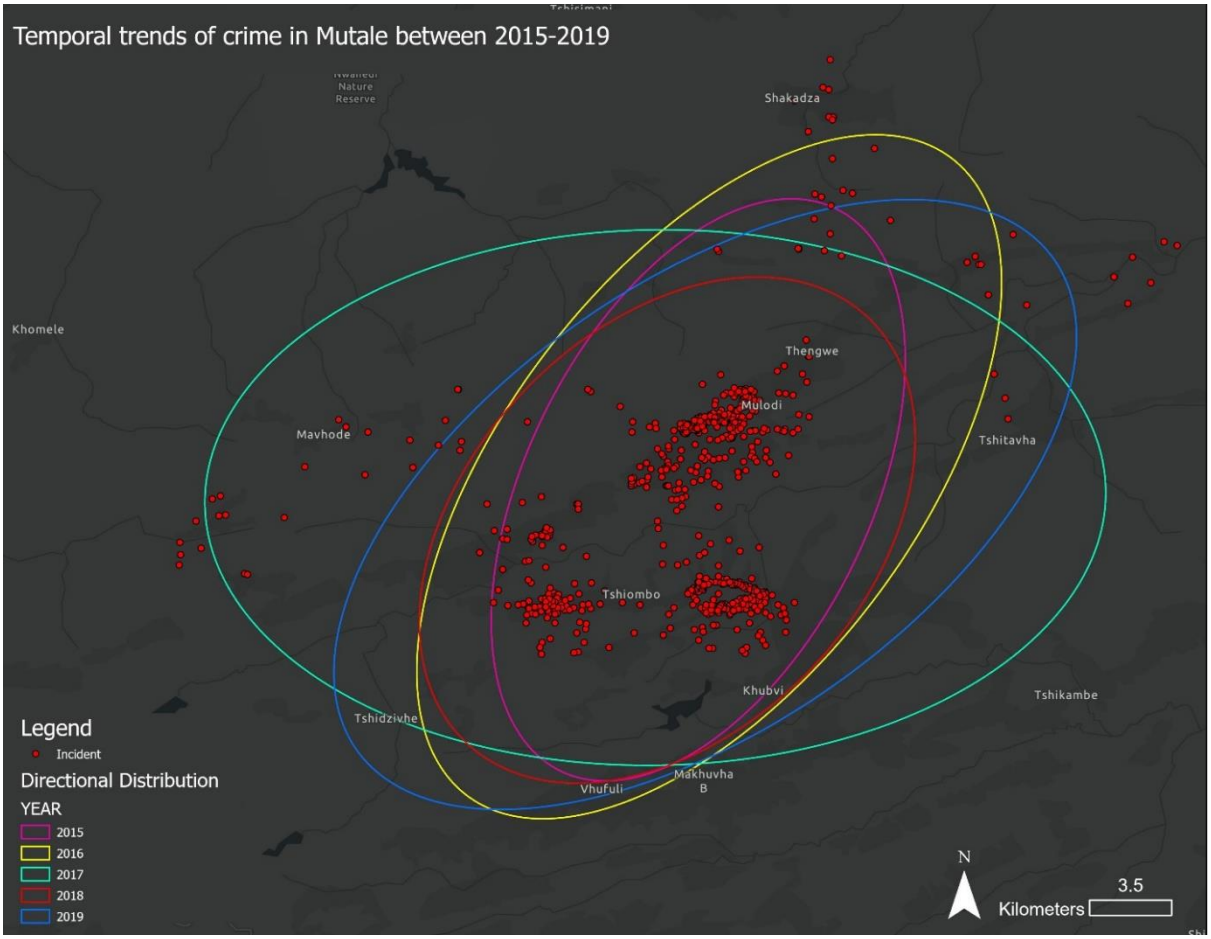

Figure 15: Directional distribution of crime per year in Mutale

4.3 Factors that influenced crimes (causative factors) - Infographics

Bar charts were used to determine the causative factors of crime prevalence in Tshaulu, Mutale, and Thohoyandou. Data clock charts were used to determine crime prevalence based on months between 2015-2019 in three study areas.

This bar graph below presents the key causative factors contributing to crime occurrence from 2015 to 2019. The graphs display a comparison of the frequency or impact of each factor, helping us understand the primary drivers behind the observed crime trends during the period. The graph provides a concise visual representation of the relative importance of these factors in influencing crime rates over the five-year period. Each year is represented as a separate bar, and the height of each bar reflects the strength of the correlation between causative factors and crime occurrence.

4.3.1 Causative factors of crime occurrence in Tshaulu area

Understanding the factors that contribute to crime is essential for addressing and mitigating its impact. In Tshaulu, domestic violence stands out as a significant causative factor influencing crime rates. In 2015, 2016, and 2017, "domestic violence" consistently emerged as the predominant causative factor behind crime in Tshaulu (Figure 16). This three-year trend underscores the significance of addressing issues related to domestic disputes and violence prevention within this specific community. However, in 2018, a significant shift occurred, with "poverty" taking precedence as the leading causative factor (Figure 16). This transition suggests that economic challenges and financial disparities played a pivotal role in driving crime during that year. By 2019, "unemployment" emerged as the primary causative factor, further highlighting the complex relationship between economic factors and crime patterns. Rising unemployment rates likely contributed to the heightened crime rates observed during this period. Tshaulu does not have a lot of variation, indicating a stable trend. The slightly consistent length of the error bars for alcohol and substance abuse in this rural region indicates a stable trend in reported data, suggesting a relatively constant impact of alcohol and substance abuse as a causative factor for crimes from 2015 to 2019 (Figure 16). Similarly, the error bars for domestic violence exhibit a steady length, signifying a consistent level of reported incidents related to domestic violence as a factor contributing to crimes in this rural region during the specified period. The length of the error bars for the remaining causative factors is more uniform than in the other areas, once again highlighting a steady trend in the reported data, demonstrating a

consistent impact of these factors as contributing elements to crimes in this rural region from 2015 to 2019 (Figure 16).

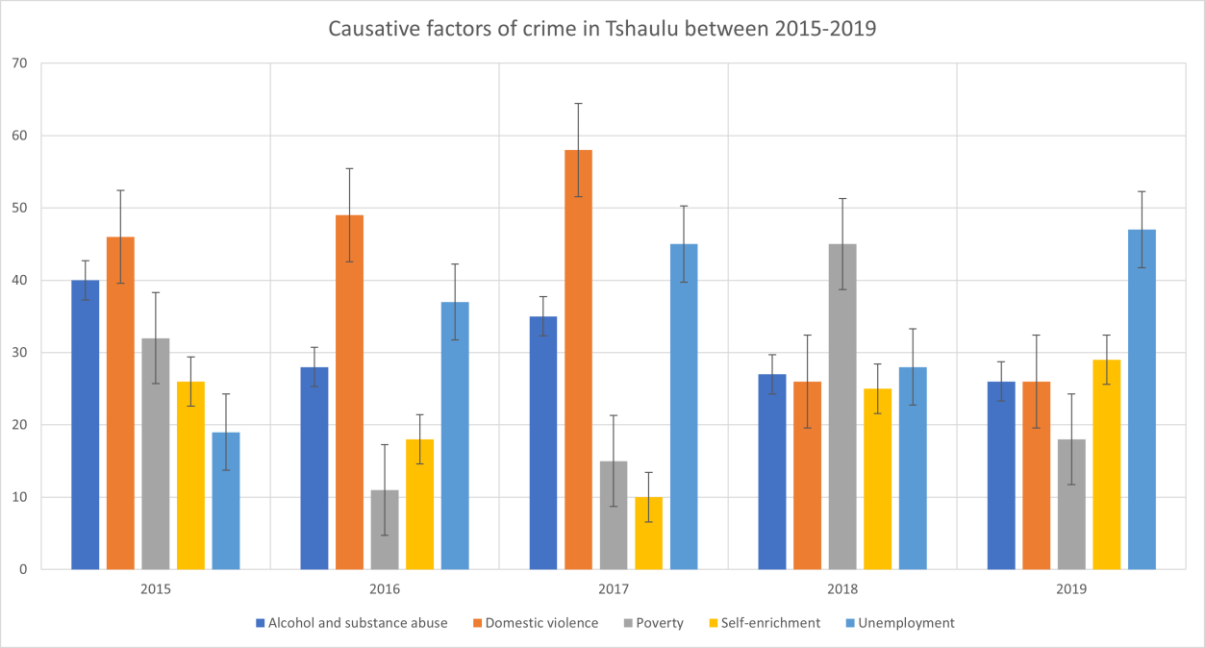

Figure 16: Factors contributing to crime at Tshaulu from 2015 -2019

4.3.2 Causative factors of crime occurrence in Thohoyandou area

Figure 17 vividly illustrates the dominant influence of unemployment as a causative factor for crime in Thohoyandou. From 2016 to 2019, "unemployment" consistently took the forefront as the primary causative factor for crime, with 2019 being its highest. According to Statista, the unemployment rate in South Africa from 2016 to 2019 has been on the rise, except for 2017, where it dropped to 23.99% from 24.02% in 2016. While “self-enrichment" emerged as the second leading causative factor behind crime incidents in Thohoyandou (Figure 17). The alcohol and substance abuse as causative factor error bars in this region suggest high variability in the reported data, signifying fluctuations in the influence of alcohol and substance abuse on crime rates from 2015 to 2019, which is the same case for domestic violence, there is also variation. Like the other factors, the error bars for poverty, self-enrichment, and unemployment display varying lengths, representing fluctuations and uncertainty in the reported data over the specified period (Figure 17).

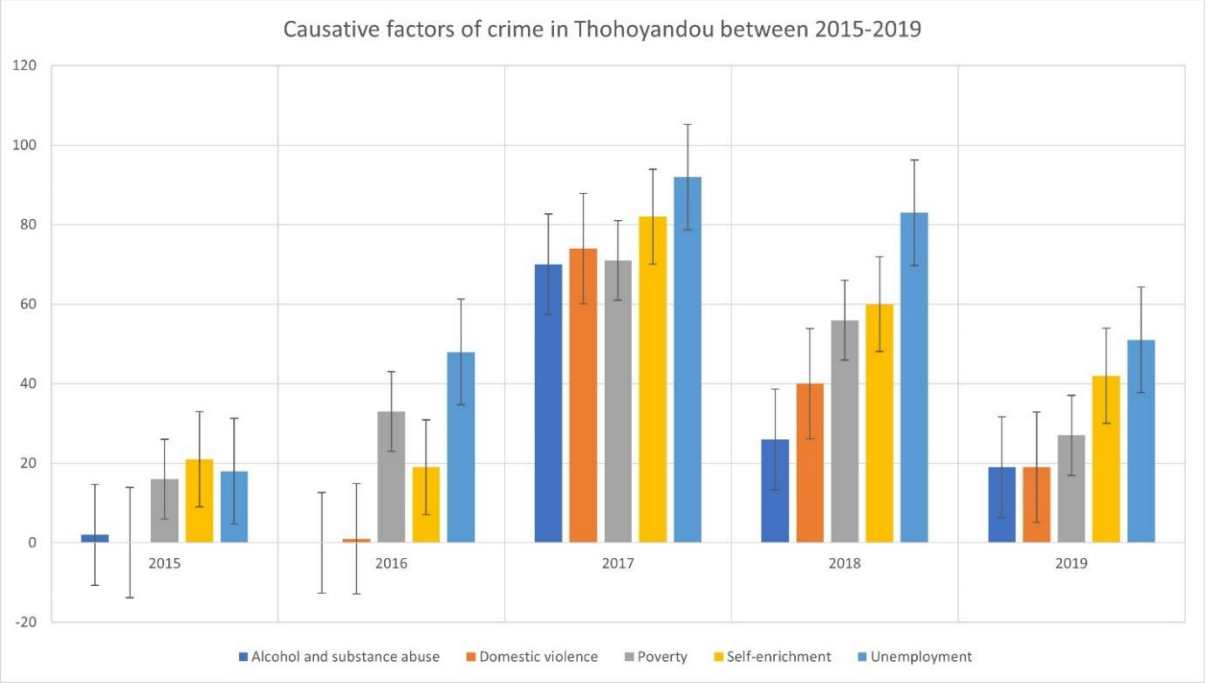

Figure 17: Factors contributing to crime at Thohoyandou from 2015 -2019

4.3.3 Causative factors of crime occurrence in Mutale area

Economic factors and financial stress might have contributed to individuals engaging in criminal activities for personal gain. By 2018, "domestic violence" had taken centre stage as the primary causative factor. In 2019, a return to "alcohol and substance abuse" as the leading factor suggests a recurring issue or persistent challenge (Figure 18). The error bars associated with the bar representing alcohol and substance abuse in this region demonstrate notable variability in reported data over the years. This suggests fluctuations in the impact of alcohol and substance abuse as a causative factor for crimes during the period from 2015 to 2019 (Figure 18). For domestic violence, the error bars on the bar graph portray a considerable range of values, indicating fluctuations in reported incidents related to domestic violence as a factor contributing to crimes in this area. The varying lengths of the error bars highlight the uncertainty in the reported statistics. The error bars associated with illiteracy, poverty, self-enrichment, and unemployment illustrate fluctuations and uncertainty in the reported data over the years (Figure 18). They convey the variability in the impact of illiteracy, poverty, self-enrichment, and unemployment as contributing factors to crimes in this region during the specified period.

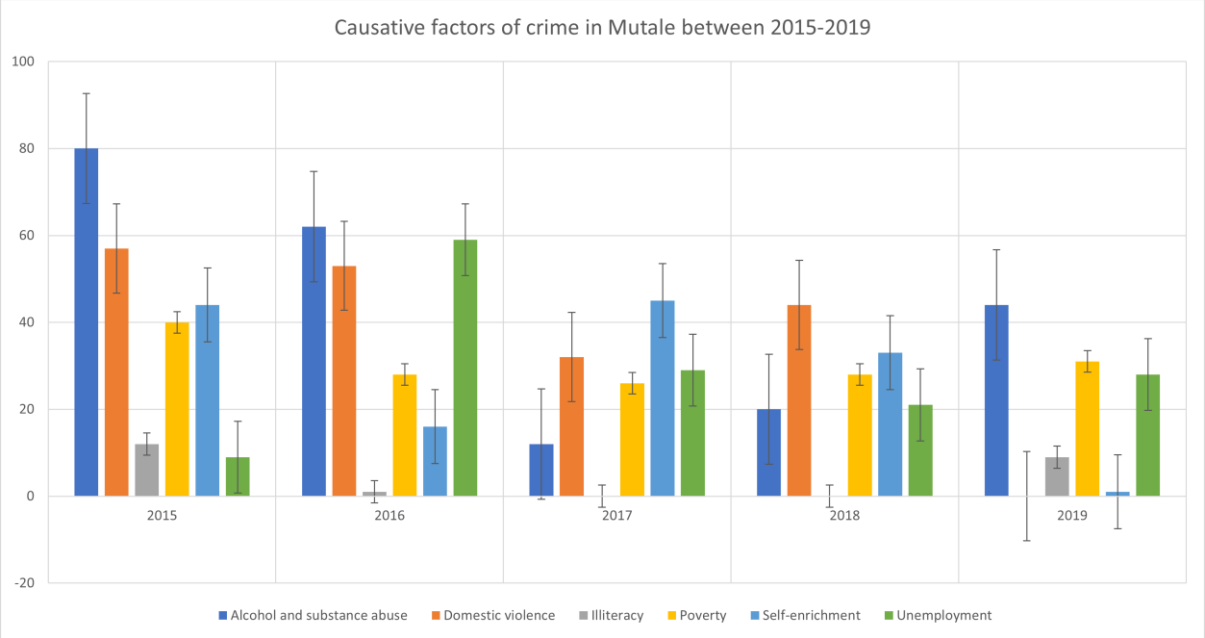

Figure 18: Factors contributing to crime at Mutale from 2015 -2019

4.4 Data clock for crime incidences results analysis

In this study of crime incidents within a region, I further employed data clocks to gain insights into the temporal patterns of criminal activity over a five-year period (from 2015 to 2019). A data clock is a circular chart that divides a larger unit of time into rings and subdivides it by a smaller unit of time into wedges, creating a set of temporal bins. Bins are symbolized using graduated colours that correspond to a count or summarized value taking place in each period. The data clock presented in the figures visually represents our findings.

4.4.1 Crime occurrence by Month at Tshaulu area from 2015-2019

In Tshaulu, we saw more reported crime incidents from December to May. The clock reveals that there were high crime incidents in April of 2018 as well. The area shows yearly fluctuations, especially in January, with 2019 having the highest (Figure 19). Furthermore, a high crime incident count was reported in the month of December 2015.

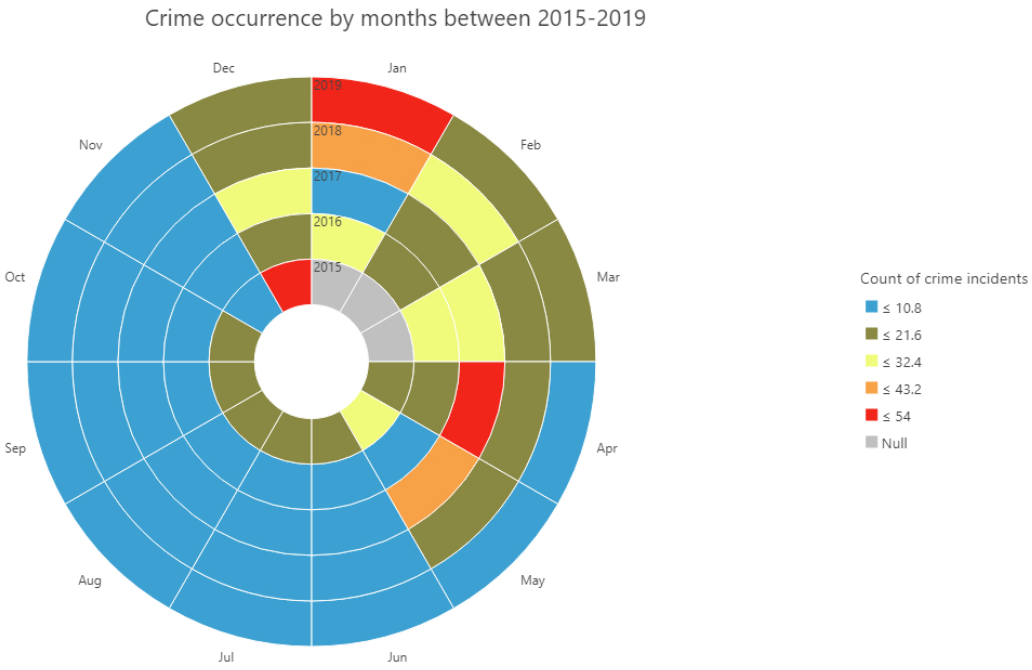

Figure 19: Data clock showing yearly and Monthly crime incidents for Tshaulu

4.4.2 Crime occurrence by Month at Thohoyandou area from 2015-2019

Figure 20 is a data clock for Thohoyandou, representing crime analysis, and reveals interesting temporal patterns in crime occurrence over the five-year period (2015-2019). Each wedge on the clock corresponds to a month, and the colour of the wedges indicates the number of reported crime incidents for that month. Interestingly, the

December month from 2015 to 2019 shows relatively low crime incidents, while January and February have high crime incidents for the years 2018 and 2019 (Figure 20). The months of April and May of 2018 also had high incidents, with the count of crime incidents being between 80.8 and 101 (Figure 20).

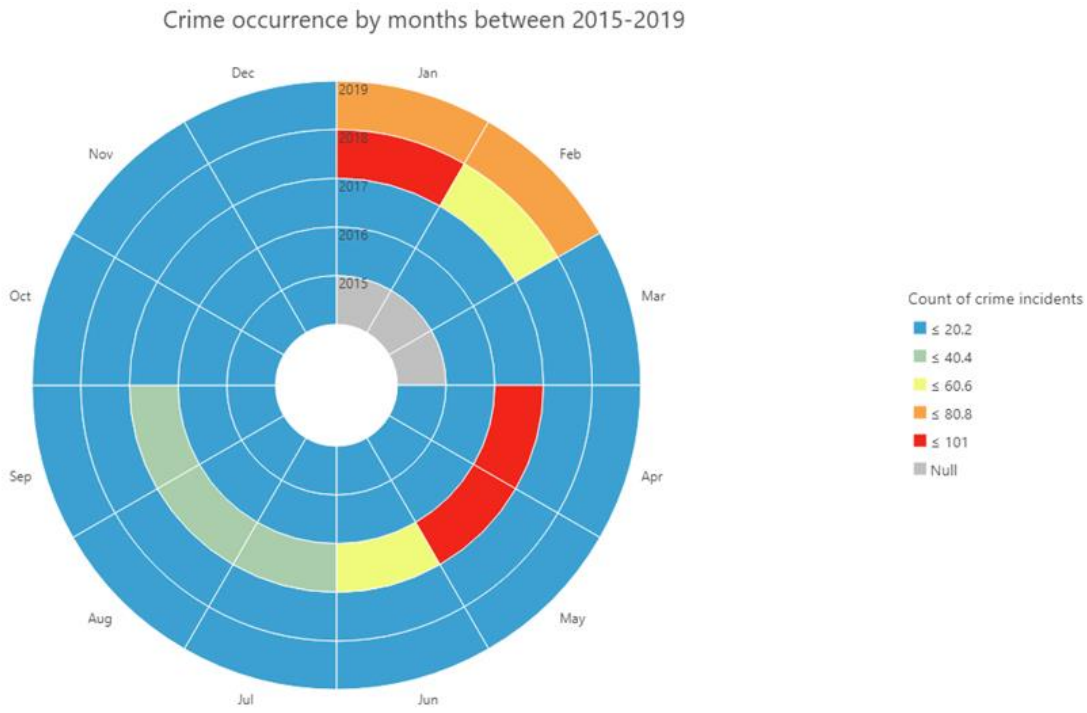

Figure 20: Data clock showing yearly and Monthly crime incidents for Thohoyandou

4.4.3 Crime occurrence by Month at Mutale area from 2015-2019

The data clock in Figure 21 is for crime prevalence in Mutale from 2015 to 2019. It offers insights into crime-occurrence trends in the area. The clock displays trends similar to those in Thohoyandou and Tshaulu, with crime rates increasing and being at their highest during January. Year-to-year variations are also visible (Figure 21).

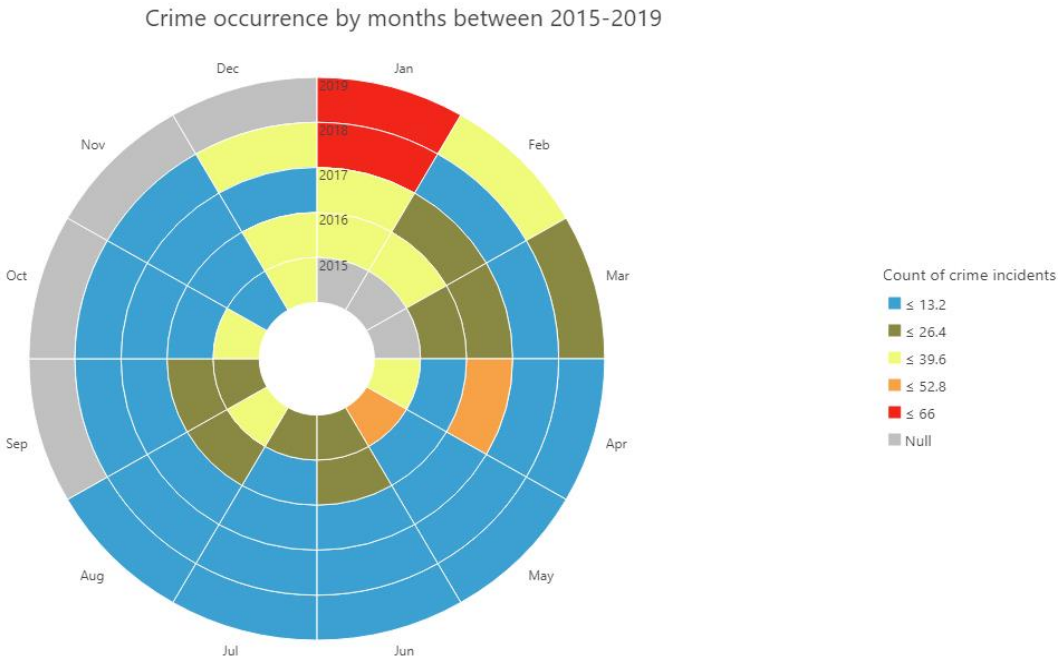

Figure 21: Data clock showing yearly and Monthly crime incidents for Mutale

CHAPTER 5: DISCUSSION

5.1 Spatial distribution and temporal trends of crime from 2015-2019 in the study area

Among many areas in Thulamela Municipality, the reason for selecting Tshaulu, Mutale, and Thohoyandou and studying crime prevalences is that these are normally areas of concern when it comes to reported crime, which is different from other urban public spaces owing to their unique features such as population demographics, economic activities, their proximity to police stations and many other factors. The spatial distribution patterns of crime in these areas indicate how crime has been prevalent from 2015 to 2019. The results of the present study are important because their data can be used to predict future trends and can provide law enforcement with an idea of which regions require extra efforts to deal with crimes.

The present study utilised the cold and hotspots crime distribution index to determine the clusters of concern in the study area. The results indicate that although we observed majority of areas falling under cold spots, a significant number of areas also fell under hotspots in the region, suggesting that a different set-up of an area can be a potential hotspot for criminals. According to previous studies (Fondevila 2021; Blesse & Diegmann, 2022), the distance between a police station and a crime hotspot can influence criminals to commit various offences by taking advantage of the inaccessibility of police stations, especially in rural areas. Similarly, the present study found that most crimes occur in villages where police stations are very far and victims of crimes become vulnerable to offenders.

Looking at the results of hotspot analysis, the results from this study indicated 90%, 95%, and 99% confidence in the spatial analysis of crime hotspots in Tshaulu, Thohoyandou, and Mutale from 2015 to 2019. It can be attested that GIS is a capable tool for determining crime hotspots as compared to other traditional methods that are time-consuming and costly. Similarly, a study by Kedia (2016) agrees that the utilization of GIS for crime mapping and its analysis is effective for the enforcement of the law and the management of crime. The study demonstrates how GIS improves our overall view of crime mapping, research, analysis, and decision-making. It also makes information easier to understand for ordinary people, which helps to deter crime. However, it implies that converting to a GIS from a traditional way of crime control

necessitates constructing the necessary infrastructure and hiring qualified staff members and facilities.

To date, most research that has assessed crime occurrence has used data from traditional sampling, which includes visiting the crime scene and analysing the data using traditional methods such as police crime records sheets. The use of GIS in crime analysis has provided the basis for defining the precise GIS tools into which observation of crime incidences is prevalent. An examination of housebreaking, pick pocketing, murder, and public violence in various areas of South Africa has shown that the criminals are no longer scared of the law, and in most cases, these crimes occur to the most vulnerable individuals and communities with a lack of support for law enforcement, as attested by Wesburd (2015). These findings imply that crime in Thulamela Municipality rural areas may be more concentrated than average compared to industrialized towns, which have been the focus of most studies on crime concentration up to date. Further investigation is necessary to determine the causes of these variations in crime concentration levels, although population density, crime rate, and distribution of opportunity space are likely the main factors.

During a time of notable growth in crime, the high concentration of crime in the rural areas of Mutale and Tshaulu within the Thulamela municipality remained consistent. For instance, the percentage of hotspots where 75% of robberies were concentrated stayed at 15% between 2015 and 2019 in Thohoyandou, when there was an18% rise in robberies. These findings are similar to the hypothesis put forth by Ajimotokin et al. (2015), which suggested that an increase in crime in rural areas is associated with poverty and unemployment. This was evident in the current analysis, which implies that variations in opportunity space and population density variables may be more plausible explanations for differences in crime concentration levels than differences in crime levels.

We identified various risk factors that were associated with the assessed crime. The strongest risk factors to predict crime are consistent across years (2015-2019), as well as the ratio of police versus community populations subjected to victimization. Pie charts on temporal trends also illustrated that while crime is concentrated in Thulamela local municipality, there are many areas around this region where crime does not occur at all, especially in the Mutale region. This phenomenon may be due to fewer economic

activities in the Mutale area. In this case, I feel there is no need to provide crime support to such areas; however, monitoring must be done from time to time to find out any element of criminality. The methodology and findings of the present study are very useful in advancing the theory of crime in micro-places, as well as the potential identification of crime hotspots.

5.2 Factors influencing crime prevalence

The presence of opportunity for crime does not guarantee the commission of a crime; thus, regions where crime does occur must also have other advantageous characteristics, such as being accessible to offenders and having opportunities that they are aware of. From the present study, I have noticed that crime incidences are influenced by various factors such as alcohol and substance abuse, domestic violence, illiteracy, poverty, unemployment, and self-enrichment. All these factors are considered individually centred since offenders commit crimes for various reasons. The identified factors are very similar to those that have been identified by Janko and Popli (2015); Grobler and Joubert (2004); Kim et al. (2019). This implies that the locations where chances for crime to happen are further limited to the places where other additional favourable conditions must also exist (i.e., absence of policing in an area). These favourable conditions are probably unique to some crime types (like robbery from the person, and house burglary) and overlap with others (like robbery from the person, and theft from the person and house burglary).

From the results of the study, In 2015 and 2016, alcohol and substance abuse emerged as the dominant causative factors behind crime occurrences in Mutale and Thohoyandou. These two years witnessed a consistent association between increased substance abuse and higher crime rates, reflecting the impact of addiction on criminal behaviour in this area. In 2017, a noteworthy change occurred, with "self-enrichment" becoming the leading factor. This shift may indicate a rise in financially motivated crimes, such as theft and fraud, during this period. In some of the interviews, the residents indicated that there is an element of gangsterism that has drawn the attention of the police in the area, and this has significantly increased.

For each study area, approximately 77% of crime occurrences per month were identified using the data clock method to have experienced a significant increase in robberies across various months and years and directional distribution maps to

elucidate crime spots. 77% of crime occurrence is still a high number, and typically too big for any targeted resource deployment. Areas with high crime concentrations are normally small in coverage but require strong and massive deployment to deal with, as perpetrators are sometimes armed. Therefore, this suggests that determining high crime concentration locations could provide a more effective way to choose places to prioritize in the first place to deal with criminals. Yang (2019) explains GIS-based criminal hotspot analysis as the best approach to combat crime, while providing evidence-based on the type of crime, occurrence, and factors influencing such crime activities.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Objective 1: Determining Spatial Distribution – Hotspot Analysis

In pursuit of the first objective, I employed the Hotspot Analysis (Getis-Ord Gi*) tool to unveil spatial clusters of crime prevalence. The analysis pinpointed distinct hotspots where crime incidents were significantly concentrated. Furthermore, the Optimized Hot Spot Analysis allowed me to fine-tune parameters, enhancing the accuracy of identifying these clusters. This spatial exploration illuminated specific geographic areas where crime seems more prevalent.

Objective 2: Understanding Temporal Trends – Directional Distribution (Standard Deviational Ellipse)

To address the second objective, I harnessed the power of Directional Distribution analysis, as depicted through Standard Deviational Ellipses. This tool enabled us to identify directional trends in crime occurrences over time. My observations revealed consistent and inconsistent patterns, with crime rates surging at the beginning of the year in January and decreasing towards the middle of the year and the beginning of winter. The utilization of directional distribution ellipses allowed for a more comprehensive understanding of how crime patterns evolved across the years 2015 to 2019.

Objective 3: Uncovering Influential Factors – Infographics

The third objective delved into the intricate web of causative factors influencing crime prevalence in the studied areas. Bar charts effectively showcased the changing landscape of these factors, revealing shifts in prominence from year to year. This insight guided an understanding of the societal dynamics and external influences shaping crime behaviours. Additionally, data clocks illuminated temporal variations in crime occurrences, emphasizing the importance of considering monthly fluctuations when formulating crime prevention strategies.

In conclusion, multifaceted crime analysis not only deepened our understanding of crime patterns but also provided actionable insights on the types of crimes that happen in different areas. By employing a diverse array of spatial and temporal

analytical tools, I unearthed trends, clusters, and causative factors, understanding the socio-economic factors that play a role in the count of criminal activities that happen all over the country. As we continue to grapple with the multifaceted challenge of crime prevention, this comprehensive analysis serves as a foundation for data-driven strategies that can enhance public safety and well-being in Tshaulu, Mutale, Thohoyandou, and similar regions.

Several studies have demonstrated the use of GIS in determining crime prevalences in different regions across the globe based on the well-established observation that crime concentrates in space (Shafique et al., 2017; Yang, 2019; Mohammed & Baiee, 2020). The majority of research on crime concentration to date has focused on rural areas, which has helped to understand the crime hotspot, occurrences and factors influencing such crimes. This study is one of the first to conduct comprehensive, rural community- and crime-specific analyses of crime concentration trends in the Thulamela municipality setting Housebreaking, pickpocketing, murder, and public violence were found to be the most prevalent crimes committed by offenders in the Thulamela Municipality. The present study has found that crime incidences are influenced by various factors, such as alcohol and substance abuse, domestic violence, illiteracy, poverty, unemployment, and self-enrichment. These results support Weisburd's (2015) law of crime concentration, which states that a small number of locations account for a large percentage of crime. The rule is generally valid.

6.2 Recommendations

Based on the comprehensive analysis of crime patterns, temporal trends, and causative factors in the areas of Tshaulu, Mutale, and Thohoyandou from 2015 to 2019, several key recommendations emerged to guide law enforcement agencies, policymakers, and community organizations in their efforts to enhance public safety and reduce crime:

- Targeted Policing and Resource Allocation: Law enforcement agencies should strategically allocate resources and personnel to the identified hotspots and areas with persistent high crime rates. Ensuring a visible police presence and rapid response in these locations can serve as a deterrent and help maintain public safety.

- Seasonal Crime Prevention: Recognizing the seasonal fluctuations in crime rates, authorities should implement seasonal crime prevention initiatives. These could include enhanced community policing during the summer months and specific strategies to address the unique challenges posed by the winter months.
- Economic Support Programs: Given the strong correlation between unemployment and crime, local governments and community organizations should prioritize job creation initiatives and support programs to combat poverty. These efforts can help reduce the desperation that often drives individuals to criminal activities.
- Substance Abuse Intervention: Addressing the recurrent issue of alcohol and substance abuse as a causative factor requires a multifaceted approach. Community-based substance abuse intervention programs and rehabilitation services should be expanded to mitigate the influence of addiction on criminal behaviour.
- Domestic Violence Prevention: In areas where domestic violence consistently ranks as a leading causative factor, robust domestic violence prevention programs and support services should be in place. Promoting awareness, providing counselling, and ensuring swift legal action can help protect victims and deter perpetrators.
- Data-Driven Decision-Making: Continuously collect and analyze crime data to monitor changing patterns and emerging trends. Regularly update crime prevention strategies based on the latest insights and adapt to evolving conditions.
- Community Engagement: Foster community engagement and collaboration with law enforcement agencies. Empower local communities to be proactive in reporting and preventing crime, as engaged citizens can play a pivotal role in crime reduction efforts.
- Education and Awareness: Launch public awareness campaigns to educate residents about crime trends, prevention strategies, and the importance of

reporting crimes. Informed and vigilant communities are better equipped to safeguard their neighbourhood.

- Interagency Cooperation: Encourage collaboration among various agencies, including law enforcement, social services, and healthcare, to address the complex interplay of factors contributing to crime. A coordinated approach can yield more effective outcomes.

Implementing these recommendations with a focus on data-driven decision-making and community involvement can lead to more effective crime prevention and contribute to safer and more prosperous communities in Tshaulu, Mutale, Thohoyandou, and beyond.

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