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Criminal Geography and Geographical Profiling within Police Investigations – A Brief Introduction

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Abstract

Understanding the interaction between geography and crime has a long tradition throughout the world. If successfully deconstructed and understood, criminal geography can be used to help police strategically target increasingly scarce resources to prevent and reduce crime, as well as helping police investigators to locate and arrest serial offenders. Geographical Profiling (GP) or Geographical Offender Profiling (GOP), revolves around the premise that information regarding crime-related locations can be utilised and scrutinized to identify the most probable location from which a serial offender is based. Using purpose-built computerised decision support systems, underpinned by psycho-geographical theory and research derived from similar known offender spatial behaviours, police investigations can be assisted in many ways. Most notably, by plotting the known crime locations within a particular crime series, decision support systems are able to generate 'hot-spot' areas of high probability and priority. Importantly, this provides police investigators with actionable geographical information which can be used to direct resources towards a likely offender base location and thereby rapidly narrow down large suspect pools into a more manageable number. Contemporary police application of traditional GP methods are discussed.

Key terms: *Geographical Profiling; Police Investigation; Hot-spot Analysis; Decision Support Systems; Psycho-geography*

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Geographical Profiling

The scientific study of criminal behaviour has a long history. Indeed Psychologists and Criminologists have long sought to prevent crime and reduce reoffending through efforts to better understand what motivations underlie offending behaviour and how decisions regarding suitable offence locations, timing, frequency and victim selections are made (Armitage & Smithson, 2007; Boduszek et al., 2021; Cole & Brown, 2014; Debowska et al., 2015; Hammond, 2014; Hunt, 2021; Mann, Mojtahedi & Leadley, 2020; Roach & Bryant, 2015; Willmott, Boduszek & Robinson, 2018; Willmott & Ioannou, 2017). Geographical Profiling (GP) or Geographical Offender Profiling (GOP) revolves around the premise that information regarding crime-related locations can be utilised and scrutinized to identify the most probable location from which a serial offender is based. Defined as "a criminal investigative methodology that analyses the locations of a connected series of crime[s] to determine the most probable area of offender residence" (Rossmo, 2012: 144), GOP is a research informed investigative technique, that refers to the process of identifying and analysing crime locations, to formulate insight about offenders and more specifically, where the perpetrators of particular offences are likely to be located (e.g. residing, frequenting, working). Research exploring criminal spatial behaviours have consistently demonstrated how the locations that offenders target are not random and are both consciously or unconsciously predetermined (Canter, 2007; Canter & Youngs, 2009; Lino, Calado, Belchior, Cruz & Lobato, 2017; Lundrigan & Canter, 2001; Synnott, Bakker, Ioannou, Canter & Van Der Kemp, 2018). Practically, the determination of the most probable offender locations can help to reduce the total search area required by law enforcement allowing police investigators the ability to prioritise resources and possible suspects, whose known base locations are found to reside within high probability areas (Lino, et al., 2018; Rossmo & Velarde, 2008).

The modern development of GOP techniques emerged from the early work of Criminologist's such as Kim Rossmo from Canada and Investigative Psychologist's such as David Canter from the UK, although the exploration of spatial behaviours can be traced back to as early as the 19th century. André-Michel Guerry (1833) first explored the interaction between crime and location, recognising the need to examine variation in the geographical distribution of crimes throughout French provinces in an effort to identify geographical crime patterns. Likewise, in his attempt to understand geographical patterns in offending behaviour in Victorian London, Henry Mayhew (1861) recognised early on that locations that presented an attractive and lucrative opportunity for crime, were likely to be the base location for many prolific or would be offenders. Attempting to narrow

the suspect pool in such high crime areas to aid police investigators, Mayhew theorised that most offenders do not travel great distances to commit their crimes. By drawing upon principles from a variety of disciplines such as Environmental Psychology and Criminology, more recent efforts to identify offender locations by Rossmo and Canter led them to simultaneously develop theoretical and practical models of spatial behaviour with the intention of gleaning insight into offenders' crime patterns. Although GP involves the analysis of crime locations, what underpins the technique goes beyond simply connecting dots upon a map, so that the psychological processors which lead an offender to perpetrate a crime at a given location, can themselves be more readily understood (Canter & Youngs, 2010). Moreover, understanding how offenders make use of their day-to-day environments and familiarity with a given area when committing their crimes, assessed through consideration of the activities which may contribute to an individual's spatial awareness (e.g. place of residence, routes to work, recreational activities), provides a basis for investigating geographical aspects of offending. Research to date has displayed that crime locations can in themselves highlight particular geographical localities which are in some way significant to the offender and their offences (Canter & Youngs, 2017; Lino et al, 2018; Wiles & Costello, 2000). For instance, Routine Activities Theory (Cohen & Felson, 1979) posits that a crime occurs when there is a converge in time and place between three factors; (1) a motivated offender, (2) a suitable victim, and (3) the absence of capable guardian, to prevent or deter the crime from taking place (though see Sutton, 2018 for an alternative perspective). More recent theorising and empirical research continues to suggest the convergence of these three phenomena are most likely to occur during the offender's daily 'routine' activities (Rebocho & Silva, 2014; Rossmo, 2012).

Geo-Spatial Theories of Crime

Fundamental principles of GP in understanding decisions made by offenders about locations in which they choose to commit their crimes, derives from the concept of propinquity and morphology (Canter & Youngs, 2009). Propinquity relates to the closeness of crime locations to the offenders' life, in which the probability of the distance of the crime location significantly decreases as the distance travelled by the offender away from their base location increases (Canter & Youngs, 2009). The second principle, morphology, relates to the overall pattern of the distribution of the series of crimes around the offenders' base (Canter & Youngs, 2009). The term 'base' defines locations that are frequented by an offender during non-criminal activities (e.g., home, place of work, place of frequent recreational activity) and are believed to form the anchor-point of many offenders' criminal spatial patterns. Both propinquity and morphology encompass a variety of models that

individually explore a particular aspect of an offender's spatial behaviour. For propinquity, one of the fundamental approaches to understanding the significance of crime location choice concerning the offender's base, is the principle of *distance decay*. In short distance decay posits that the liklihood of offending will decrease as the distance from the offender's base increases (Turner, 1969). Recent empirical support for the distance decay function was found by researchers examining lone offender vehicular terrorist attacks in Jerusalem and the West Bank (Hasisi et al., 2019) and a study of sexual offenders in the US (Chopin & Canepplele, 2019). However, offender and victim characteristics as well as offence type, are all variables which moderate the distance travelled by offenders (Emeno, & Bennell, 2013; Gill, Horgan & Corner, 2019). Distance decay can be explained as a product of routine activity and rational choice. That is, offenders will frequently identify suitable locations for crime during routine non-criminal activities (Brantingham & Brantingham, 1993) and will typically consider the potential costs and rewards of their decisions when choosing where to offend (Cornish & Clarke, 1987). Whilst offenders are less likely to commit crimes the further they travel from their base location, they are also found to travel a short distance away from their base before perpetrating any crimes. Described by Turner (1969) as a 'buffer zone', offenders are found to maintain a minimum distance from the immediate area of their base location in an effort to avoid being recognised by potential witnesses familiar with them (Lino et al., 2017) which serves as a conscious location based decision designed to reduce the risk of being apprehended. One recent study also displayed the importance of capable guardianship as a likely determinant for offending locations which impacted offender geospatial decisions regarding the size of this buffer zone. Moreover, a study of property and homicide crime locations in the Buenos Aire displayed a non-random spatial concentration of offences whereby crimes increased exponentially as the distance from the nearest police station increased up to a distance of 500-600 meters (Fondevila et al., 2021). Together, the area between the buffer zone and the end decay region can be identified as a would-be offender's 'criminal range', in which the individual will target familiar locations to commit their crimes.

In relation to morphology, one fundamental aspect of exploring the pattern of distribution of an offender's crimes around their base location, is the Circle hypothesis. Developed by Canter and Larkin (1993) after their examination of known offenders' crime locations, the theory proposes that by creating a circle around the distance between the two furthest linked crime locations as the diameter, the area circumscribed by the circle is likely to contain the offender's base (e.g. current or previous residence, work place etc.). In what is referred to as 'hot-spot' regions or anchor points, this concept has been supported by a mass of research findings which over time displayed that by

taking offenders known outer crime locations (linked through behavioural similarity), the perpetrator was commonly based within the circled locality and often towards the centre of the circle. An early example of this was displayed by Goodwin and Canter (1997), whose research found that in 85% of the offence series' that were examined, that had been linked to a common offender, the perpetrator was discovered to be living or otherwise operating, within the circled region encompassing their crimes. Whilst the circled region of the outer offences may still constitute a large area, it provides police investigators with an empirical means of vastly reducing their suspect pool and focusing on a more probable area where the offender is likely to be operating from. The reduction in time and cost of investigative resources (i.e. search costs) thereby becomes undoubtedly apparent. However, the Circle Hypothesis is not without criticism, based in part on what is widely perceived to be its oversimplicity (Kocsis, Cooksey, Irwin, & Allen, 2002). In fact, much contemporary research from varied cultures and societies has often failed to find evidence which substantiates the hypothesis, with evidence that at least 20% of offenders live or operate outside of the area which circumscribed their offences (Goodwill, Kemp & Winter, 2013). Goodwill et al (2013) concluded that generating GP's about likely offender locations using the circle hypothesis alone, is an inherently flawed investigative strategy. Despite this, the idea is still utilised and valued by some investigators and geo-profilers, particularly when the offender is not considered to be commuting into the area to commit their offences based upon other available evidence. A recent case exploration of 15 convicted serial killers who offended throughout Brazil (2009-2015) found support for the circle hypotheses with 67% of offenders located within the circle surrounding the two outer known offence locations (Lino et al., 2018). As such, the circle hypothesis is thought to have some investigative value when used as a 'rule of thumb' estimator early on into development of a geo-profile and when used in particular cultural and social contexts (Goodwill et al., 2013).

The second fundamental aspect of morphology extends upon the idea of the circle hypotheses when comparing the spatial relationship between the offenders' crime location selection and their base location - leading to a proposed dichotomy of geo-spatial offending patterns where offenders are classified as either 'Marauding' or 'Commuting' offenders. Marauders can be identified as having their base location situated within their *criminal range* and therefore their crime locations are bounded by the location of their anchor point (Canter & Youngs, 2008; Lino et al., 2017). Marauding offenders are found to travel relatively shorter distances away from their base location to offend before returning, moving out in different directions with subsequent crimes due to temporal and mental buffers (Canter & Youngs, 2009; Paulsen, 2007). In contrast, commuting offenders

travel further distances away from their base locations to offend which results in their home base being located outside of their criminal range and thus outside the realms of a circular hypothesis (Canter and Youngs, 2008; Paulsen, 2007). This may arise due to the geometry of the city, the type of crime perpetrated, or the targeting of specific victims to name a few (Canter & Youngs, 2017).

Exploration of the marauder/commuter dichotomy and spatial behaviours of offenders indicate that the type of crime perpetrated can influence the likelihood of whether the offender will display marauder or commuter behaviours. For instance, early studies reported that commuter offenders can be identified in 43% of stranger sexual assault offenders (Alston, 1994), 52% of burglaries (Kocsis & Irwin, 1997), and 51% of serial rapists (Warren, Reboussin, & Hazelwood, 1995). Commuter offender patterns have also been identified in 49% of serial arsonists in Japan (Tamura & Suzuki, 2008) and 63% of commercialised robberies in Finland (Laukkanen & Santtila, 2006). Despite these findings, however, there are some methodological limitations associated with criminal spatial behaviour research that should be addressed. For instance, research exploring the spatial behaviours of offenders usually include the analysis of information that is only known post-apprehension and would not be known to law enforcement and police investigators during the live investigation of the crime – including the offender's age and criminal experience (Laukkanen & Santtila, 2006; Meaney, 2004). Likewise, there are currently limited systematic guidelines or empirical evidence available to determine the accuracy in identifying whether an offender is a marauder or commuter when analysing the crime locations alone until the individual is caught and thus must be viewed with caution (Canter & Youngs, 2017; Lino et al., 2017; Paulsen, 2007).

Nevertheless, by combining and integrating the theories discussed, as well as research into the journey to crime distances (Snook, Wright, House, & Alison, 2006), and offence type variations (Canter and Youngs, 2008), GOP aims to generate a form of intelligence that can assist police investigations. Here, recommendations that are somewhat evidence-based can be made within a live investigation (recognising the limitations associated with cultural and regional context). With this aim in mind alongside the apparent need for real-time tools to support the investigative process, decision support systems have been developed.

Geographic Information Systems

Advancement in mapping technologies led to the development of numerous Geographic Information Systems (GIS) that incorporated many of the criminal spatial behaviour theories and empirical findings discussed above into a more practical analytical tool that can be easily employed

by law enforcement practitioners and researchers (Butkovic, Mrdovic, Uludag & Tanovic, 2019). At present there are at four popular GIS available (*Dragnet, Rigel, CrimeStat, Predator*) that are considered useful estimator tools for identifying an offender's probable base location.

For example, *Dragnet* is a GIS developed specifically as an operational decision support tool in response to the need to provide investigators with greater opportunities to identify and apprehend serial offenders. Based upon the minimum effort principle, Dragnet utilises a negative exponential algorithm based upon the distance decay function with the view that the likelihood of locating an offender's base location will significantly decrease the further the crime locations become (Lino et al., 2017). Once crime location information within a given offence series are computed and input into the GIS, Dragnet creates mathematically based models of crime site locations, allowing potential search regions to be defined (Canter & Hammond, 2006). More importantly from a police investigator perspective, using such empirically generated models, the software presents the results of this mathematical algorithm of the crime locations identified via a colour-coordinated probability 'plot' (known as a Probability Surface) that informs the user of the priority regions in which the offender(s) are most likely to reside within (for an example see Figure 2 below). Therefore, in relation to specific crime series under consideration, the Dragnet system allows investigators to refine and narrow search areas where the offenders are most likely to reside or have some anchor point, as well as highlighting the varying degrees of prioritisation that should be assigned to such areas. It is worth noting that several alternative geographical profiling systems also exist and are available such as the Rigel Criminal Geographic Targeting system (Rossmo, 2000) and the Predator system (Godwin, 2003) which are based upon similar mathematical algorithmic principles as Dragnet. Similarly, CrimeStat IV journey to crime routine (Levine, 2002), is a GIS more directly based upon Bayesian probability principles and operates without any psychological underpinnings or framework, while more recently the GeoCrime (Butkovic et al., 2019) GIS combines automatic and manual techniques for the analysis of spatial and probability distribution of crime sites. The benefits of GeoCrime is that the GIS already incorporates Google Mapping Software which is currently absent within other GIS packages (Butkovic et al., 2019).

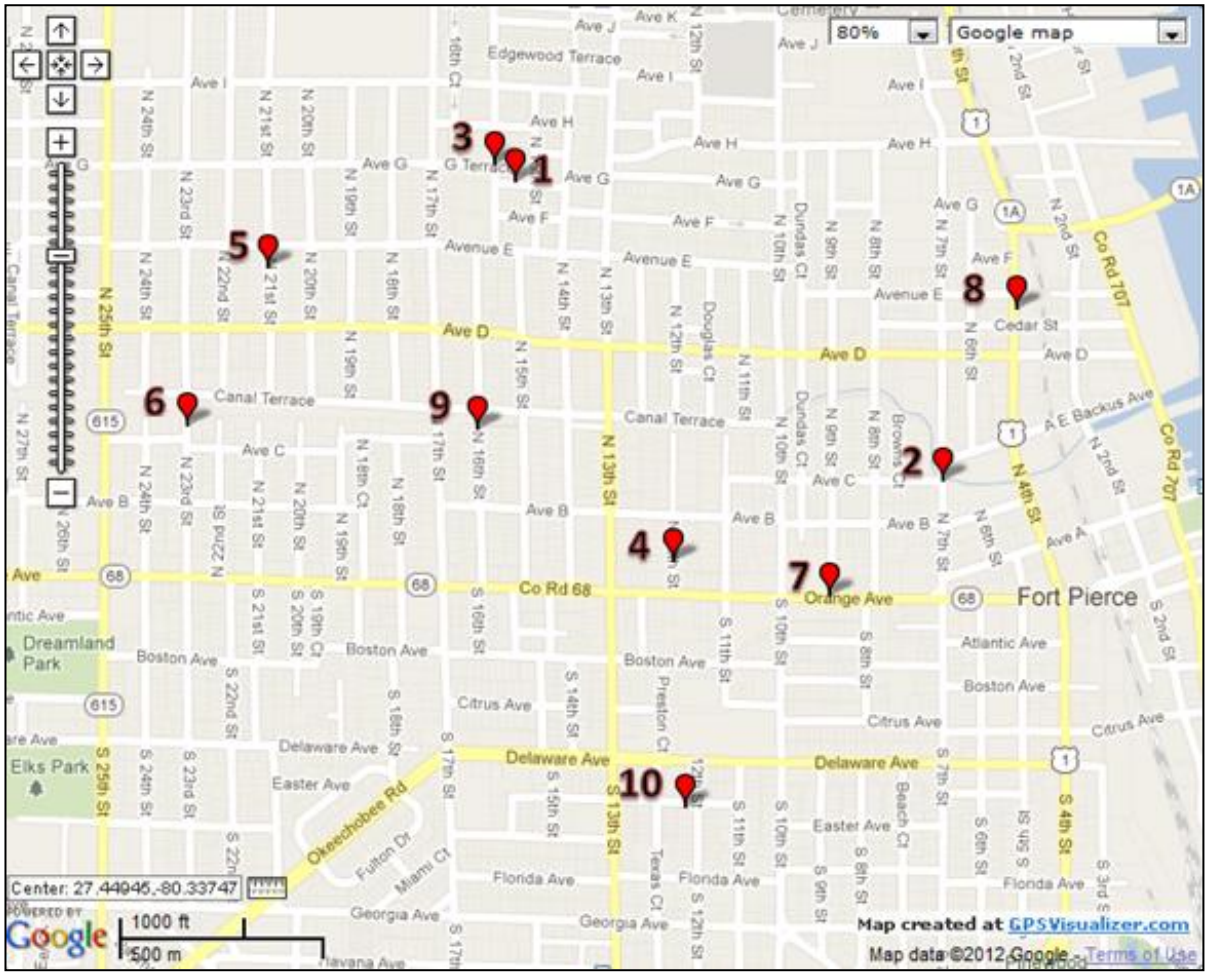
Despite the apparent success of some of these alternate systems, the power and accuracy of the Dragnet system has been argued by Canter and his colleagues, drawing upon research explorations and real-world investigative use (see Canter et al., 2000; Canter & Hammond, 2006; Canter & Youngs, 2017). Underpinnings which Dragnet developers believe to be responsible for various police forces making use of the system around the world. However, as with any predictive

modelling technology or systems, outcomes are reliant on the accuracy and relevance of the data from which they are based. As the nature and context of crime and criminality continue to develop, advance and change, so too must the empirical evidence which underpin the geo-profiles which emerge from these systems in order to ensure accuracy and efficacy.

A note of caution regarding the efficacy of such GIS tools is also offered by Paulsen (2007), who argues that as the majority of empirical evidence surrounding geographical profiling tools have simply compared the accuracy of the systems when using case studies and post-crime samples, how applicable these systems are within live on-going criminal investigations and for crimes that are not physical location-based such as, cybercrimes remains to be seen. In addition, GIS are only effective if they are able to fulfil a series of requirements which include; the crimes being perpetrated by only one offender, a minimum of five crime locations are present, the offender has not moved into a different area during the crimes, the distribution of the crimes are relatively uniform around their residence (i.e. a marauder offender), and that the offender did not change their anchor point during the crimes (Rossmo, 2000; 2012). Despite the associated limitations and required fulfilment of the principles of the crimes for maximum effectiveness, GIS systems have been found to provide accurate probable search locations for the offender's base (Canter et al., 2000; Sarangi & Youngs, 2006). In fact, a recent review of international use of GP displayed that GIS computerised software remains a popular investigative tool used by police around the world for a wide variety of crime types. Computerised GIS software were typically valued, considered to be accurate and useful within police investigations though some evidence displayed GP's were used operationally even when optimum conditions for use were violated. For an in-depth review of practitioner's views on the utility of such GOP methods see Emeno, Bennell, Snook, and Taylor (2016). Some contemporary evidence also supports the use of such GIS tools within modern cybercrime investigations with Butkovic et al. (2019) displaying utility of tailor-made GIS software such as GeoCrime in identifying offline base locations for serial cybercrime offenders within Europe.

Figure 1

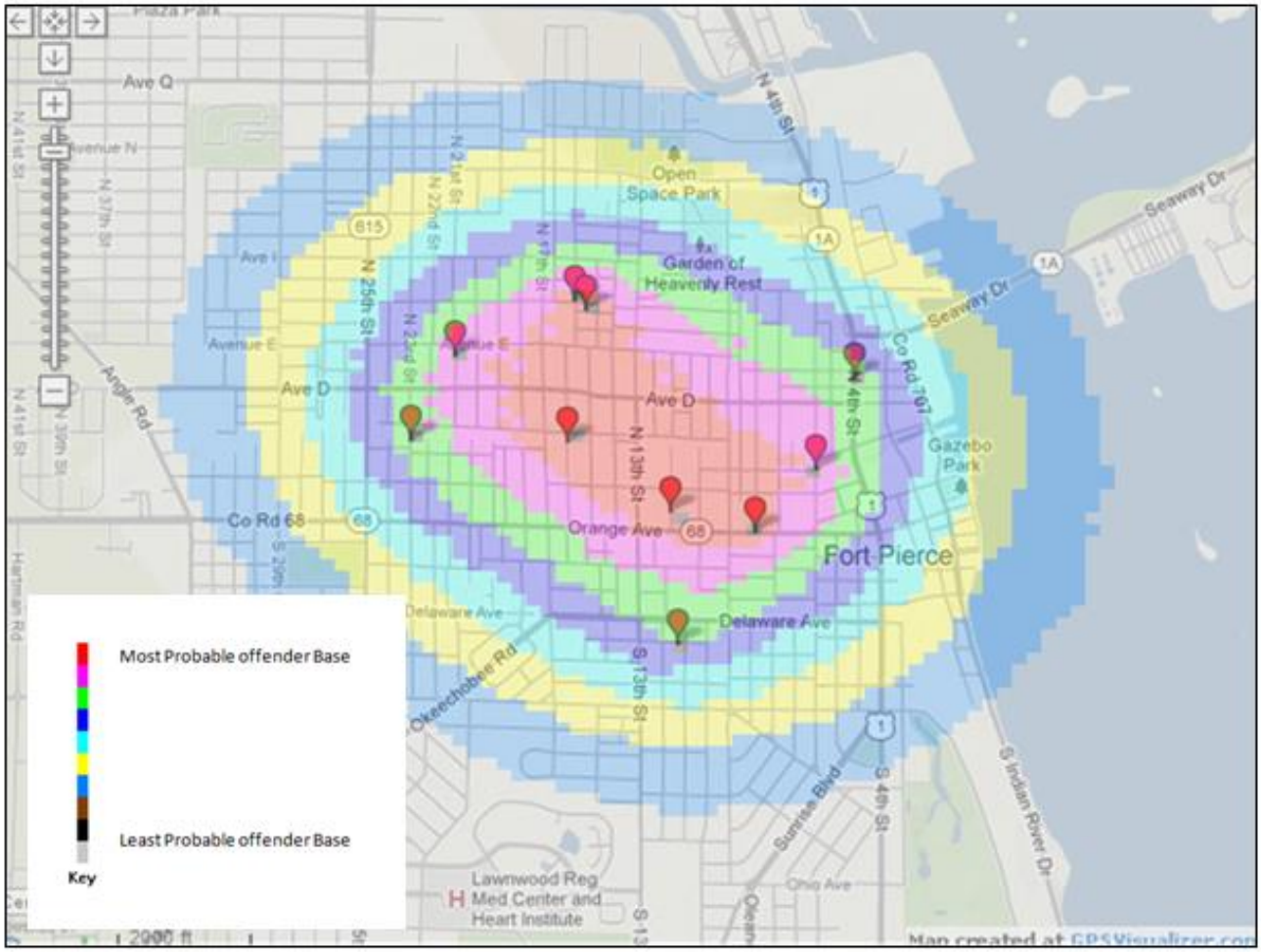
Example hypothetical robbery offence series locations numbered in the order committed and pinpointed the location of that crime.



As previously highlighted a geographical analysis produced in relation to a given crime series under investigation is conducted by plotting the individual addresses of each of the linked crimes onto a map (see figure 1 example above). Using each of the locations unique 'geo-codes' (see appendix 1), these locations are subsequently transposed into the chosen profiling system which relative to the scale of the map used, will allow for the likely offender(s) base to be profiled to varying degrees of probability.

Figure 2

Example Prioritised Analysis Generated by GOP software of ten linked robberies offences in the hypothetical series portrayed in Figure 1.



(Number of offence locations = 10, Mean inter-point distance between crimes = 2.1km).

The prioritised probability surface map above displays the area where the offender(s) were most likely to be based at the time when the robbery series occurred in the present example, with the red coloured 'hot-spot' area highlighted as representing the most probable base location. As the probability regions move further outwards through the green, purple, blue and yellow regions, the probability of the offender living in these areas decreases. The least probable offender locations appear beyond the robbery series inner circle, in accordance with Canter and Larkin's (1993) Circle Hypotheses (see appendix 2 in relation to the present robbery example).

Interpreting a Dragnet Geo-Profile Analysis

It is worth noting what the Dragnet probability outputs cannot account for in a given analysis of mapped crime locations, is the geographical makeup of the surrounding landscape. Therefore, human consideration of factors which may influence where an offender lives or is operating from is required, irrespective of the probable value attained. For example, using the robbery series example (see figure 2), part of the ocean is included within the geographical profile output. Notably, however, such areas can be eliminated from any investigative search efforts where it is clear that they offer no investigative value.

Highlighting the most likely offender base location in the regions shaded red and purple (see figure 2), without representing an exact 'X marks the spot' position, means that geographical profiles are able to display to police investigators that the offender(s) base location is likely to be focused at the centre of this particular crime series. Using such information, investigators can prioritise their suspect lists and systematise the expenditure of police resources accordingly. Within the majority of investigations, this will often result in lower search costs for the eventual identification of the offender (Canter & Youngs, 2017; Snook, 2004). In the robbery example provided (Figure 2), after taking the distances between offences into account, the profile generated suggests that the perpetrators could be 'marauding' or travelling relatively short distances to commit the robberies at the time the offence series occurred, with the mean distance between crimes equating to just 2.1km.

Adding weight to the accuracy of the likely offender(s) home or base location based upon the pattern displayed in any geographical profile developed is a body of research and empirical findings into the Marauding offender as discussed. Canter and Youngs (2008) suggest the combination of such research allows for certain assumptions to be made about the Marauding offender. Namely, that the offender has a base somewhere within the area of the crimes being conducted and therefore in an attempt to conceal their base location, tends to put distance between adjacent crimes (see figure 1 and 2). Similarly, offences are often relatively evenly distributed which may provide patterns and behavioural indicators surrounding the offenders' likely next offence location (based upon average distance travelled). However, it is worth noting that criticisms continue to surround the small samples, limited geographic regions and outdated basis to much of the empirical research which underpins such GIS systems and geo-profiles. Despite the continued use and popularity of GP's by police investigators internationally (Emeno et al, 2016), limitations surrounding the empirical research from which GIS geo-profiles are generated, undoubtedly serves to limit their efficacy within contemporary police investigations (Woodhams et al., 2021).

Research conducted by Meaney (2004) exploring 83 successive burglary incidents, led the author to conclude that the first offence in a series is likely to be in closer proximity to an offender's home or base location than the last offence in a series, thereby supporting the concept of temporal features to an offending pattern. Again, making use of the robbery example above (see figure 2), this notion is supported with the 'hot-spot' area identified. Having said that, not all research has concurred with such a concept and it is important for any geographical profiler or individual assisting police investigators in their use of GP's, to review contemporary empirical evidence relative to crime series offence type being investigated. For example, research by Laukkanen and Santtila's (2006) displayed that within robberies, distances did not increase as the offending series progressed suggesting the need to take offence variations into consideration. Furthermore, criticisms have also amassed surrounding the reliability of Canters' early research which formed the basis of modern-day geo-profiles developed from the Dragnet system. Importantly, the utility of early research pertaining to prevalent and more salient offending behaviours, are likely to have vastly changed and developed with the advent of modern technological advancement over recent years which offenders frequently make use of when committing their offences (Mburu & Helbich, 2015). Nonetheless, the totality of theory and research considered above displays the utility of GP's in helping police investigators to focus a proportion of investigative efforts and resources within hot-spot areas identified, particularly where the offence is time-sensitive and doing so could prevent a further offence being carried out such as terrorist attacks. Likewise, perhaps value is offered most where police investigators have very little other evidential lines of enquiry and as such, a GP provides an alternative investigative strategy that police may to introduce and pursue.

Developing an Investigative Strategy – Recommendations for Police Investigations

Formal Recommendations given to police investigators based upon any GP analysis typically focus upon elements such as:

- *Narrowing down the large pool of suspects within a given area, to the high probability areas highlighted in the GP allows for the prioritisation of potential suspects and the reduction of those who need to be investigated further.*
- *Combining use of GP with traditional policing tools may allow for the further suspect prioritisation in high priority areas. For example, searching police databases to identify known offenders who match the modus operandi (M.O.) of the unknown serial offender.*

- *Geographically focused DNA and fingerprint testing of suspects identified as matching the M.O. within the high probability areas proscribed by the GP may prove to be a useful strategy for allowing positive identifications to be made (dependent upon the allocation of resources and seriousness of the crime series).*
- *Directing neighbourhood canvassing efforts within the GP's proscribed high probability areas. Such efforts may involve local media appeals and information bulletins appealing for further information may generate new or corroborative evidence from witnesses alongside active police intelligence gathering from informants and members of the public in hot-spot locations.*
- *Based upon the high probability areas outlined, key arterial routes that appear to run through the crime series may benefit from additional police surveillance and monitoring (e.g. vehicle patrols of these routes, check points). However, repeated offender use of such routes is somewhat speculative and should be noted is not directly based upon any GP probability analysis.*
- *GP's may also be utilised to identify and select optimal positioning for covert/overt positioning of police officers or CCTV or ANPR cameras.*

Limitations and Future Directions of GP

The most prominent limitation with the reliability and accuracy of any geographical profile produced is based upon the fundamental assumptions made, which if inaccurate may distort or alter the probable offender location highlighted, as well as the investigative strategies recommended. Moreover, where any of the crimes linked in the series to a common offender were found to be inaccurate or wholly incomplete in that, more offences were committed by the perpetrator(s) responsible but were not included in the geographical analysis, may result in an alternative likely base location (and thus investigative recommendations) being identified. Such sensitivity to complete and accurate information when working within the realms of a live police investigation, with multiple offence locations, is extremely problematic with errors therefore likely to be present within GP's. Similarly, the Dragnet system operates somewhat instinctively on the assumption that the offender(s) are *marauder's* based within the inner circle of the outer offences within a given crime series. Despite research which suggests that the vast majority of offenders are likely to be locally based near to their crime series, a substantial body of research also displays that varying proportions of offenders (> 20%) are not. Given that it is always possible that the unknown offender(s) may be commuting into the area to offend, GP's accuracy is highly sensitive to such

assumptive profiling. This clearly limits the practical utility of geo-profiling and the investigative recommendations advanced. Perhaps more problematically is the evidence that suggests GP's generated from GIS', along with the theories that underpin them, may not have universal utility. Research by Hammond (2014) found that the geospatial patterns of sex offenders in New Zealand violated many of the assumptions underpinning *Dragnet* systems and as such, resulted in considerably higher search costs to locate offender bases. Similarly, recent research examining the temporal and geographical proximities of serial sex offenders in the UK found that a minority of serial stranger sex offenders committed their offences within very close geographical and temporal proximity though with some occurrences within the crime series also spanning very large distances and over a prolonged number of years (Woodhams et al., 2021). The importance of contemporary ever evolving and culturally, regionally relevant empirical data which informs the GIS used, is therefore crucial to the accuracy and utility of profiles generated from them.

Another limitation of geographical profiling support systems, such as Dragnet, is their lack of inclusion of information known about offender actions during the commission of their crimes. GP computerised systems generally fail to directly integrate with important information about a large number of offending individuals held within police databases. The combination of such information would undoubtedly offer greater investigative value than the analysis of crime geography alone. More recently, *interactive Offender Profiling decision support Systems* (iOPS) attempt to go beyond the analysis of simple crime geography and instead seek to integrate police databases and research findings in real-time so that behavioural aspects of offences can be scientifically profiled concurrently. This may contribute to building more detailed and complete geo-behavioural offender profiles in the future. However, as yet this system is not thought to be fully operational and therefore the value of such tools remain limited and unproven (Chainey & Tompson, 2008; Tomkin et al, 2019). Such a system would however allow police investigators to more conclusively link cases to common offenders under a process of comparative case analysis, thus allowing live investigations to review and possibly link additional cases to a given offender. Clearly such an approach allows for richer inferences based on geo-behavioural information to be made with a higher degree of certainty about the perpetrators responsible.

Concluding Comments

Despite the practical utility and investigative value ascribed to geographical profiling as a means of identification of high probability hot-spot areas, permitting suspect pools to be substantially narrowed, police investigators must bear in mind the limitations of the approach. Doing so will

ensure that police efforts to identify the perpetrator, do not become geographically restrictive. As such, any geographical profile (GP) ought to be treated as one possible line of enquiry whilst keeping an open mind in regards to other investigative possibilities. Notably, that offenders may also be commuting criminals or that as a result of factors such as limited data sharing between different police forces or agencies, additional information may elicit a somewhat different geographical profile. Nonetheless, as an immediate investigative aid and used as just one line of enquiry alongside more traditional policing methods, especially where suspect information is scarce in a given case, the geographical profile would provide a possible new informative dimension within particular investigations. With vast and rapid developments being made to understand and improve the general utility of GP methods (Butkovic et al., 2019; Emeno & Bennell, 2013; Emeno et al., 2016; Snook et al., 2006; Tomkin et al, 2019), a more scientific and reliable future for GOP may well be on the horizon. Variation in the use and application of GP's may also be possible in the future, including to locate body deposition sites or identify kidnapped victims confinement locations, as opposed to an effort to identify an offenders likely base location.

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Appendices

Appendix 1 – Geo-location codes of each offence within the Robbery crime series example

"***Original address"- latitude - longitude***

Offence 1 - "1600 avenue G, Fort Pierce", 27.4561703,-80.3396402

Offence 2 - "700 avenue C, fort Pierce", 27.4495801,-80.3289622

Offence 3 - "1600 G Terrace, fort Pierce", 27.4565703,-80.3401581

Offence 4 - "113 N 12th Street, fort Pierce", 27.4477818,-80.3356968

Offence 5 - "510 N 12th Street, fort Pierce", 27.454284,-80.345807

Offence 6 - "406 N 23rd street, fort Pierce", 27.4507992,-80.3478249

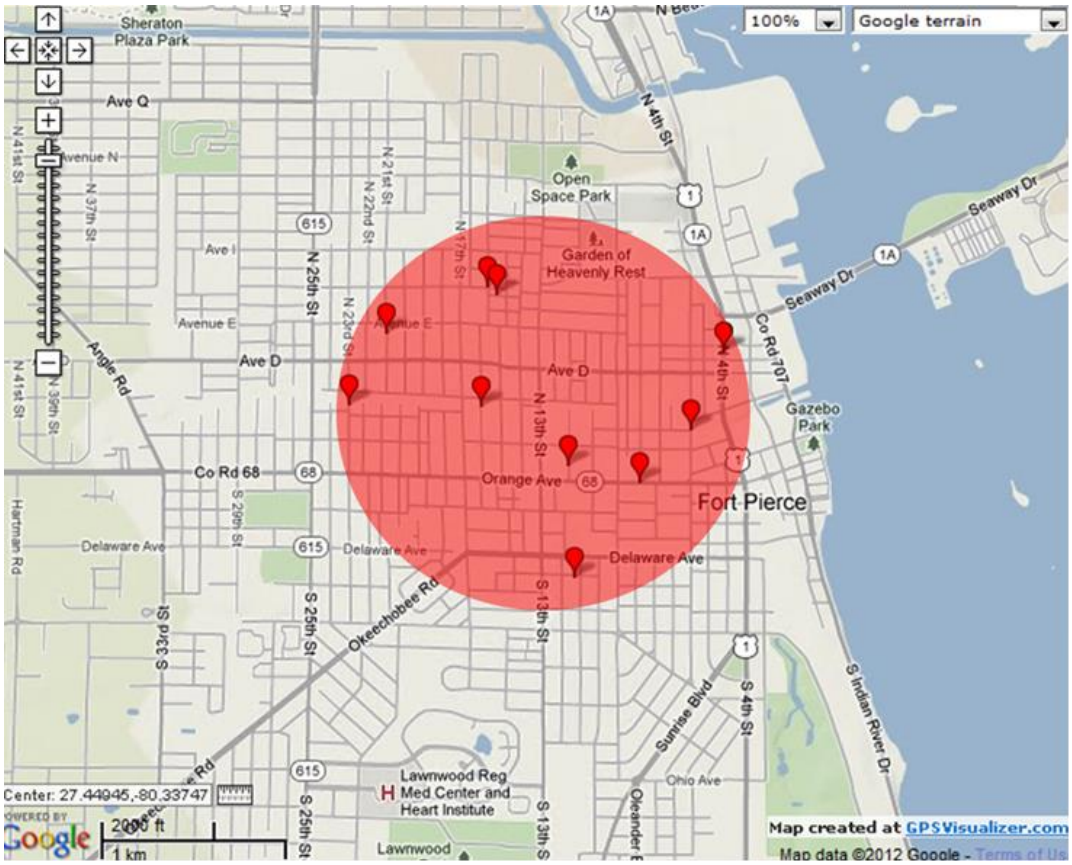
Offence 7 - "900 Orange Avenue, fort Pierce", 27.4470084,-80.3317648

Offence 8 - "531 S, US 1 highway, fort Pierce" [N 4th street], 27.453389,-80.327117

Offence 9 - "1600 Canal Terrace, fort Pierce"[N 16th street], 27.450723,-80.340571

Offence 10 - "601 S 12th street, fort Pierce"[Easter avenue], 27.442331,-80.335371

Appendix 2 – Circle Hypothesis plot of Robbery Example Offence Locations



Reviewer 1 – Accept pending minor revisions

Dr Terri Cole
Principal Academic in Forensic Psychology and Programme Leader for MSc in Investigative Forensic Psychology Bournemouth University

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This summary gives a useful overview of the area of geographic profiling and its potential utilisation in crime investigations.

Initially I found the title of the piece in relation to 'geographical offender profiling' confusing and would recommend a potential change to 'geographic profiling', as not all of the work is in relation to profiling an offender. This also links to the section describing recommendations from such work – there are many other uses - for example, methods can be used to locate deposition sites or identifying optimal positioning of cameras or officers.

In addition the focus may not be on suggesting the likely area of residence, more often an anchor point of some kind may be identified, but this could be where the offender is staying, a previous address, a work location or the like – it need not be restricted to an offender 'residence' which should be made clear.

Finally, much advice is not based from GIS, for example there can be great utility gleaned from pre and post offender movement and analysis of pavement bias and the like which can assist in prioritisation.

Overall however this is an excellent summary of both the theoretical underpinnings (e.g. rational choice theory) and some of the practical applications (e.g. GIS) of geographic profiling. It includes both description and detailed evaluation, providing objective analyses of the considerations and utilisation of such work.

Author response

Thank you for your review of this manuscript. All revisions recommended have been made prior to publication.

Reviewer 2 – Accept pending minor revisions

Dr Shannon DeBlasio
Lecturer in Forensic Psychology and Criminology, Arden University

This paper provides a comprehensive overview of Geographical Profiling (GP), whilst offering some historical context as well as practical recommendations for the field. The authors recognise both the value and potential limitations of GP for police and law enforcement and encourage practitioners to consider implementation of GP as a tool for focussing resource in a 'hot spot', rather than a guide for decision making. Having read widely on Geographical Profiling during my early career, I am confident that this article covers the key literature in the field, providing the reader with a clear and concise overview of GP theory and research. The tone and depth of the piece is well suited to an online journal such as IJC, and I therefore support publication of the manuscript subject to minor amendments.

Recommendation - the paper requires a thorough proofread to eliminate any spelling/grammar mistakes. Once addressed, this paper is supported for publication within the Internet Journal of Criminology.

Suggested amendments

Page/Line	Suggested Amendment
3/3	Addition- have long sought to prevent crime
3/12	Deletion- "
3/16	Addition- are not random, and are both
4/14-18	Comment- Revision of closing sentence
4/21	Spelling- concept
4/23	Addition- offenders' life, in which
5/16	Comment- Revision of wording, 'of the distribution of the'
12/27	Spelling- pursue
13/4	Comment- Removal of the line break

Author response

Thank you for your review of this manuscript. All revisions recommended have been made prior to publication.