

# OPERATIONALITY OF GEOGRAPHIC PROFILING THROUGH A HYPOTHETICO-DEDUCTIVE METHOD. A REVIEW OF CONSTRAINTS AND FACTORS

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## Abstract

This paper is dedicated to the identification of the constraints and factors enabling the computation of an effective geographic profile, with the specificity of focusing only on the elements that could be available during an investigation. It aimed at filling the gap between the inductive demarche of environmental criminology and the deductive, operational procedure followed by geographic profilers. It reviews successively the relationship between the premeditation, the seriousness of the facts, the nature of the offences and the spatio-temporal pattern of the crimes with the criteria required to build effective likelihood surfaces in geographic profiling. A decision tree is provided as a tool for evaluating the risks of an ineffective geographic profile with regard to the non-respect of the different conditions.

## Keywords

environmental criminology, decision making, inference, serial offenders, geographic(al) profiling, spatio-temporal analysis

## Résumé

*Cet article est dédié à l'identification des contraintes et facteurs permettant la construction d'un profil géographique efficace, avec la particularité de s'intéresser aux seuls éléments disponibles durant une enquête criminelle. L'article cherche à combler le vide méthodologique entre la démarche inductive de la criminologie environnementale et la procédure déductive et opérationnelle suivie par les profileurs géographiques. Il examine successivement la relation entre la préméditation, la gravité des faits, la nature de l'infraction et la configuration spatio-temporelle des crimes avec les critères nécessaires à la construction de surfaces de vraisemblance efficaces dans le profilage géographique. En synthèse, un arbre de décision permet d'évaluer les risques d'un profilage erroné en fonction du non-respect des différentes conditions.*

## Mots-clés:

*criminologie environnementale, prise de décision, inférence, auteurs en série, profilage géographique, analyse spatio-temporelle*

## I. INTRODUCTION: TOWARD MORE OPERATIONAL CONCERNS IN CRIME MAPPING

Pin Mapping is a common practice carried out by analysts such as geographers, statisticians and practitioners in various disciplines (epidemiology, marketing, criminology). If such approach is not recent in criminology (work of Quetelet and Guery in the 19th.), the study of the geographical environment in order to understand the offender's spatial decision process is a more recent approach developed by the environmental criminology (Brantingham and Brantingham, 1981a). Several studies in this field concern the journey-to-crime, with the elementary but fundamental finding that there is a friction with the distance (the distance decay effect) between the crime location and the offender's home or

anchor point (Phillips, 1980, Rhodes and Conly 1981, Rengert et al., 1999). According to the crime pattern theory, offenders generally are less likely to commit their crimes far from their activity nodes (Brantingham and Brantingham, 1990).

Since the nineties, Geographic Profiling (GP) presents several issues distinct from the environmental criminology (Rossmo, 1997). The principle of distance decay is maintained and makes possible to build a likelihood surface under certain conditions. However, unlike the largely inductive approach developed in environmental criminology, GP seeks the residence or anchor for an unresolved series of crimes. It corresponds to a hypothetico-deductive process. Therefore, it must rely on a model and on assumptions limiting or favouring the GP application in order to make it consistent with such a

deductive approach.

Among the first constraints that allow the application of GP, we find the classical distinction between marauder and commuter offenders (Canter and Larkin, 1993). The first commit their crimes in their home range while the latter are travelling outside it. Therefore, GP applies preferentially to marauders. Rossmo (1997) classification between poachers and hunters is quite similar, and only the actions of the former are candidates for a GP analysis. Rossmo adds yet an important criterion to which this paper returns later: premeditation. As only the marauders can be studied by GP, several analyses have sought to distinguish them from commuters. Literature suggests simple geometric but hardly discriminating theories: the circle or convex polygon theory, the nearest neighbour index, etc. Laukkanen and Santtila (2006) try to connect the distance travelled by the offender to characteristics of crime to facilitate the distinction between commuters and marauder. On the other hand Paulsen (2007) adds a valuable time criterion: longer cool-off period between offences tends to reflect marauder behaviour. However he distinguished both behaviours on the idealized geometrical criterion of the circle theory.

Behind those categories characterized by a difficult distinction, Rossmo (1997) lists other conditions to allow the creation of a likelihood surface:

- *The profile must be based on several crime scenes. It can be locations of different crimes or several places associated to the same crime.*
- *The crime scenes must have been attributed to a same offender. Rossmo and Velarde (2008:36) re-defined this postulate as: the linkage analysis for the crime series is accurate and reasonably complete (i.e. there are not a significant number of unlinked crimes that should be part of the series).*
- *The offender's residence or anchor point and the area of criminal activity must not be separated by a too long journey.*
- *The targets are distributed more or less throughout space.*
- *The offender must not change his anchor point or operates from several different anchor points during his crime series.*

However, these conditions are questionable. There is no consensus on the minimum number of crimes to constitute a series (5 according to Rossmo, least or more according to other authors). The latter condition cannot be validated in the case of an on-going inves-

tigation, without any knowledge of the offender or a suspect. Besides, the metric used to measure distances should vary according to the organization of the road network. Generally, the environment, as perceived and described in North American cities, is different from that of the old European cities (street network, density, etc.) what can lead to quite distinct distribution of targets and crimes (Brantingham and Brantingham, 1990) as well as different micro-spatial offender's behaviours (Alston, 1994 and 2001).

The use of GP in an operational situation is only possible under favourable conditions, which can only be inferred from the characteristics of the recorded crimes. *"This will include everything that the police may know before the offender is identified"* (Canter, 2011: p6) However, what is the relationship between the crime characteristics and the GP applicability? Recent literature in geographic profiling (e.g. Knabe-Nicol and Alison, 2011, Canter, 2005) tries to answer to this question. It recognises that such a deductive approach requires a theoretical framework as well as hypotheses strictly defined on both the offender's decision-making behaviour and on the way to deal with available spatio-temporal information.

In order to improve the operability of geographic profiling, this paper has for objective to identify the constraints and factors enabling the computation of an effective geographic profile, with the specificity of focusing only on the elements that could be available during an investigation. It aimed at filling the gap between the inductive demarche of environmental criminology and the deductive, operational procedure followed by geographic profilers. Inspired by Capone and Nichols (1975), (i) the kind of offence, (ii) elements from the crime scene and (iii) temporal aspects will be analysed through their relationship with the spatial dimension.

## II. CONSTRAINTS FOR THE APPLICATION OF GEOGRAPHIC PROFILING

What are the circumstances for which an application of geographic profiling may not be effective? The determination of the constraints aims at answering to this question. A constraint is a binary, excluding criterion that implies two possible situations: the respect or not of the constraint. If this one is not respected, the implementation should be rejected.

Constraints will be discussed successively through several characteristics that generally maybe inferred from the crime scene: the seriousness of the facts, the premeditation and the relationship between the victim and the offender. The reader may consult (Douglas et al., 1992) for explanation on the relationships between the crime scenes elements and those characteristics.

### A. The seriousness of criminal activities

The seriousness of the crimes influences the resources spent for the investigation and the information collected by the police force.

A priori both petty and violent crimes could benefit from a geographic profiling. However, in practise, petty crimes are too numerous and treated by diverse municipalities so that the spatial and temporal information collected for such facts is too often incomplete to implement GP analyses. Besides, victim's expectations for such offences are lower so that fewer resources are spent for solving them.

It is worth noting that, with time, mapping and GIS-like softwares (eg: CrimeSTAT, RIGEL, Dragnet respectively developed on the research works of Levine, Rossmo and Canter) have reduced the time and the qualifications required to apply GP techniques. Today literature proposes examples of GP applications to less serious offences such as vehicle theft (Tonkin et al., 2010) or burglaries (Laukkanen et al., 2008).

Nevertheless these last studies neglect the way the offences could be linked together before the solving of the investigation. Crime series is defined as several crimes attributed to the same single or group of suspect(s). Tracing techniques such as DNA, ballistic, etc. are the best and often the only way to demonstrate or at least suppose the belonging to a series. Failing that, a comparison of the modus operandi is at least required to link offences. For these many reasons, violent crimes involving thorough investigations are often better connected to each other.

Moreover GP is always based on some offender's spatial or spatio-temporal behaviour. In order to build this hypothesis, it may be necessary to resort to psychological profile which is mainly studied for violent crimes. The VICAP (Violent Criminal Apprehension Program -United States) and the VICLAS (Violent Crimes Linkage Analysis System - Canada, United Kingdom, Belgium, etc.) allow a systematic tracking of the recidivist offenders by identifying the similar behaviours and modus operandi. And these systems are again focused on violent crimes and attempts (sexual offence, murder, kidnapper, child luring).

### B. The premeditation

The distinction between premeditated and not premeditated acts is fundamental to apprehend the spatio-temporal hypotheses on the offender's behaviour. For series of violent crimes, premeditation presupposes one or more choices on the part of the offender: victim (specific or specific type), place and time, and possibly

the route to follow to reach or leave the crime location from or towards a single anchor point.

In premeditated acts, offender is driven by the crime, what Elffers (2004) calls a crime-led journey. This concept is crucial as it reflects a logical, calculated behaviour that suits well to the rational choice theory. Premeditation may involve a prior identification of crime sites and journeys, which is not without consequences in the analyse of the offender's travels. In contrast, the opportunistic crimes are more influenced by external choices without a specific choice of victim. In those situations, the influence of environmental factors can affect the consistency of the offender's behavioural (Alison et al., 2002). This, in turn, makes difficult the connection with the other crimes of the series.

The major difference between opportunistic and premeditated decisions is that the journey followed to commit the offence in premeditated acts is driven by the rational choice. The minimisation of distances in the journeys-to-crime is mainly based on this theory, considering that travelling far from the anchor point has a cost (Beauregard et al., 2007, Brantingham and Brantingham 1990).

In opportunistic situations, places and moments are randomly chosen. At best, it can be assumed that opportunistic crimes are committed in a low risk area what corresponds to an offender's known spatial environment. It could be not far from his residence, but equally not far from any well-known location such as relative's residence, work place, shopping place, etc. In such situations, the anchor point is probably not constant in the series, making event more difficult the implementation of GP. These observations explain why GP should be restricted to premeditated behaviours.

Premeditation also underlies the categories of "organized" offenders (vs. disorganized) identified by Ressler et al.(1988) and "ritualistic" offenders (vs. impulsive) recognized by Hazelwood and Warren (2000). Paradoxically, greater mobility is observed in premeditated acts (organised and ritualistic offenders) what might seem weaken the assumption of a distance decay effect. But the principle of cost minimization, often cited to explain this assumption, only makes sense if the offender adopts a rational behaviour to reduce simultaneously his travel expenditures (time, cost) and crime risks. In Rossmo's typology (2000), geographic profiling is only applied to the hunter who leaves his residence with the purpose to commit an offence and looks for interesting target from this place. This category is explicitly linked to premeditation.

The distinction between expressive vs instrumental crimes may also be related to the criterion of premeditation. In terms of distances Fritzon (2001) mentions several studies according to which an offender travel

greater distances to commit an instrumental crime. This can be compared to the observations for premeditated acts. The meaning of instrumental may, however, differ from one author to another, implying different relationships with the concept of premeditation. In Santtila et al. (2008:346), an offence is « *instrumental when the offender attempts to achieve goals that serve some ulterior purpose which is external to the actual offence* ». According to this definition, even if premeditated, the instrumental crime will not be the final purpose of the offender. This implies that there may be inter-dependence between the journeys or spatial choices made to commit both the instrumental and the final crimes. In such a situation, instrumental crimes should not be directly introduced in a geographic profile.

According to Wortley (2008), an instrumental violence is defined as “ *a planned attack with a clearly formulated purpose while an expressive violence is an impulsive reaction to events carried out in the heat of the moment* “. With regard to this definition for which the premeditation criterion is explicit, murders or sexual assault can, according to the circumstances, be classified as instrumental or expressive offences. In this case, it is clear that GP profile will be much more effective for instrumental offences.

This section shows that distinguishing premeditated and opportunistic events before applying GP is very important. For this reason, the premeditation has to be estimated, before any geographic profile, by agents specialized in behavioural analyses. They may evaluate it thanks to elements from the crime scenes such as the use of weapons, similar modus operandi for several offences, etc. A large literature exists on the subject but is not the purpose of this article.

### C. The nature of criminal activities

The nature of criminal activities plays a key role in the creation of a geographic profile. Typologies based on the offender’s characteristics are often restricted to a single type of activities because of the different spatial or behavioural hypotheses they imply. Typologies based on offender’s characteristics are often built for a specific crime type as behavioural hypotheses will be different for burglars or sexual offender for example. They are not governed by the same motivation; they do not have the same constraints, etc.

As this paper considers the situations favouring the application of GP, we can only focus on the types of crimes that do not contradict criteria relevant for the use of spatial and temporal data. Geographic profiling will then preferentially be applied to the most serious offences (mainly the violent crimes) due to their better documentation and the opportunity to build a series for which a rational behaviour is conceivable. Those vio-

lent crimes are homicides, rapes and sexual assaults, and arsons according to the FBI classification (Douglas et al., 1992). Burglaries may be added in the specific situation where offences have previously been linked by the comparison of modus operandi or ballistic / DNA analyses.

With regard to rapes and sexual assaults, geographical data are useless for domestic acts. Specific situations of multiple offenders have also to be excluded as it multiplies the risk of several anchor points. Apart from those situations, rapes and sexual assaults are probably the best category of crimes that can benefit from the geographical profiling. Series of offences can often be tracked with precision (DNA) while the victim’s testimony facilitates the precise determination of place and time as well as the offender(s)’description (mode of transportation, for example).

The ViCLAS system records the homicides, i.e. the deaths of a human person caused by another one. If they fall obviously into voluntary acts, only a part of them are premeditated and very few can be connected with a series. The expression “serial murder” refers to “ *the unlawful killing of two or more victims by the same offender(s), in separate events* ” (ViCAP, 2008). The presence of a cooling-off period distinguishes the serial murder from the mass murder who commits all crimes simultaneously (Lundrigan and Canter, 2001).

The serial murder can select his victims in specific categories of the society (according to the social status, the race, the religion, etc.). The more specialised is this selection, the weaker will be the relationship between the crime locations and its anchor point as the offender typically travels to very precise places where those victims are located.

The mobility is also varying according to the nature of the offences. Property offenders travel on average further than rapists (e.g. White, 1932, Rhodes and Conly, 1981 cited in Beauregard et al., 2005). For serial murders, Holmes and De Burger (1988) distinguished geographically stable and transient ones. While the geographically stable murders live, kill and dispose of the bodies in the same or nearby area for some time, the geographically transient murders travel continuously from one area to the next and dispose of bodies in far-flung places (Lundrigan and Canter, 2001). However, this last study demonstrates that the home location has a strong centralizing influence on the spatial patterns of disposal locations. The highest risk of failure for a geographic profile is then the possible change of residence between crimes for murders presenting a transient behaviour.

Finally homicides motivated by fanaticism and terrorism should be considered in isolation. Bennell and

Corey (2007) have studied the applicability of geographic profiling for terrorism. . One difficulty lies in the multitude of anchor locations as in the terrorism, criminality is organised around a widespread network of membership with multiple offenders who can live in different areas. Besides, It requires a very good knowledge of the organisation and their objective as those influence the choice of targets.” *terrorists with a specific target-selection strategy will be more likely to exhibit commuting behaviour.*”(Bennell and Corey, 2007:194)

### III. FACTORS FAVOURING THE APPLICATION OF GEOGRAPHIC PROFILING

The previous sections described non-spatial elements of criminal investigation that deeply constrain the implementation of geographic profiling. Even if not spatial, those elements already provide essential information about the possible relationship between the crime locations and the offender anchor point. This is essential to assess the validity of the spatial hypotheses underlying GP methodologies.

Complementary to the constraints, some elements may be more favourable to the implementation of geographic profiling without constituting excluding criteria. Those elements correspond to the factors which are quantitative (or ordered) criteria strengthening or reducing the relevance of an alternative (here the effectiveness of the geographic profile). The next section is dedicated to the discussion of three categories of such criteria: the offender’s characteristics, the spatial factors and the temporal properties imbricated with the spatial dimension.

#### A. Offender’s characteristics

Among the multiple social and economic factors describing the offender, three of them have a major influence on the geographical data characterizing a criminal investigation: (i) the offender’s age, (ii) the socio-economic environment where he grew up and where he lives, and (iii) its mode(s) of transportation. Those characteristics may be estimated thanks to the information provided by the victim or some witnesses.

The age and the socio-economic environment indirectly interfere on the geography of crimes via the experience and knowledge of the environment. It is accepted that the length of the journey-to-crime increases with age, younger offender’s having a more limited knowledge (Brantingham and Brantingham, 1981b). This is supported by several studies in different countries such as Canada, England, the Netherlands, and the United States but also for different types of crime such as burglary, rape, arson, robbery murder (many references in

Snook, 2004).

Mutatis mutandis, the living environment would have the same kind of influence. A rich environment is associated with a wider offender’s area of activity. This tendency is partially explained by the opportunity to travel with car as lower socioeconomic status or young age might make it more challenging to use a car and move about when committing crimes. (Snook, 2004, Laukkanen et al., 2008)

The mode of transportation is a key factor in GP analyses. Snook showed that distances to crime vary in function of the mode of transportation (Snook et al., 2005). Private vehicle, public transport and footpath are the three modes to distinguish. Different travelling speeds are associated to each of them and therefore different time distances, itineraries and even specific schedules. The private vehicle is the less constraining mode and, used alone or with another mode of transportation, it considerably widens the geographical area for the investigation while keeping limited to street network and traffic plans. The mode of transportation also influences the spatial pattern of crime locations. Public transportation implies a pattern concentrated around access locations. The more poorly the mode of transportation deserves the region, the more concentrate the pattern will be.

In the deductive process of GP, the assumption concerning the mode of transportation will then greatly influence the location and shape of the prior search area. An assumption of pedestrian behaviour will suited to the classical application of the journey-to-crimes function with Euclidean distances. Car-driver ones would require the development of other methods based on road-network distances where the distance-decay effect has less influence. Levine and Block (2011:226), among others, note that: “*more research is needed on integrating additional information to narrow the likely origin location of the offender, such as land use information and actual travel networks (e.g., roads, transit).*”

#### B. Spatial factors

As this paper aims at developing a procedure for evaluating the effectiveness of geographic profiling, the spatial properties of the crime locations, directly available for the investigation, have to be deeply taken into account. The principle according to which the characteristics of crime locations are connected to the offender’s spatial behaviour is fundamental in any methodology of geographic profiling. Geographers are familiar with the analysis of such components and this section proposes to investigate three geographical concepts: the place attractiveness, the density and the proximity.

### 1. *The place attractiveness impacts the distance decay from the crime location*

The concept of attractiveness has been deeply studied from a spatial perspective. It forms the basis of the central place theory (Christaller, 1966) according to which the urban centres with the higher levels of services are characterized by larger hinterlands than those with lower levels.

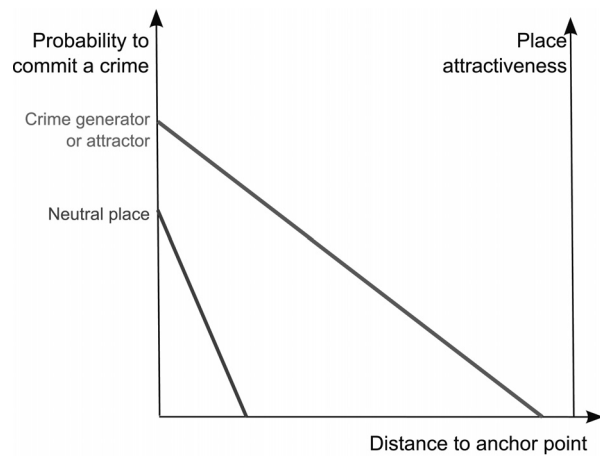
This reasoning can be transposed in the field of the environmental criminology: places offering the most criminal opportunities attract offenders who are willing to travel longer distances. Correlatively, such places are those where the proportion of local offenders is relatively smaller.

Brantingham and Brantingham (1981a) make an interesting distinction between the crime generators and attractors. The crime generators are places attracting a large number of people but for reasons unrelated with criminal motivations. By contrast, the crime attractors are particular areas well known by offenders for their criminal opportunities. Offender may travel quite long distances to reach those locations. In addition to these two categories, the same authors define the crime neutral areas as place that do not create particular offending opportunities and do not particularly attract people. When an offence occurs in such a place, there is a high probability that it was committed by a local insider. Distance decay or simple pathway models seem appropriate to model the offender's journey-to-crime for these specific places (Brantingham and Brantingham, 2008).

Does this mean that the distance decay effect does not have any influence on offenders travelling to the crime generators or attractors? Probably not and it would be more correct to postulate that the slope reflecting the decay varies with the place attractiveness. The more attractive is a location, the slighter is the slope. In the figure 1, the probability to commit a crime in a crime generator or attractor is first higher than in a neutral place as more crimes occur there by definition. Besides, the slope is very steep for neutral places as they are mainly the place of activity or awareness of local offenders.

Finally, the attractiveness is also influenced by the individual's perception and experience, which results in different spatial mobility (Beauregard et al., 2005). Some attempts exist in the literature for evaluating the "absolute" place attractiveness with a matrix of origin-destination of known offenders on the analysed territory (e.g. Levine and Lee, 2009). But this approach neglects individual's preferences. However, an evaluation of the "relative" place attractiveness may be more useful. It consists in comparing the crime locations of the series and in evaluating their respective neutrality. Sharp distance decay should be in priority applied to

the neutral locations.



**Figure 1.** The relationship between place attractiveness and the length of the journey-to-crime.

The slope of the distance decay should vary according to the place attractiveness.

### 2. *The potential index: influence on possible victims and on the efficiency of searching methodologies*

Density is the ratio between a specified population and a unit area. This concept is extremely dependant of this chosen unit area. In geographic profiling, we will prefer to focus on the potential defined as the ratio between the population and the distance which is directly in line with the application of distance decay.

At small scale, the potential is connected to the length of the journey-to-crime. In areas with high potential, the threshold to access a sufficient number of possible targets is reached at a shorter distance from the offender's residence. Of course, this distance is still function of the kind of targets that the offender is looking for. Population potential will be, for example, replaced by industrial building potential if a burglar is focusing on such properties.

At a larger scale, the potential influences the size of the buffer area (area close from an offender's anchor point and considered by him as too risky to commit a crime). It has chances to be reduced in zones with a high population potential. This must be linked to the capability of guardianship. First in such areas, people do not know well their neighbours According to social disorganisation theory, residents living in areas characterized, among other factors, by high building density are less able to perform guardianship activities. (Sampson, 1983). Secondly in the same areas, police officers have to manage a lot of potential offenders and targets what reduce their control capacities

### **3. Proximity: a central concept in crime linkage analysis**

The concept of proximity is central in the linkage of criminal activities. If the first meaning of proximity is the nearness in space or time, it must be analysed in combination with its second definition: nearness or closeness in a series. Does proximity in space and/or time help to link criminal events and to which degree of effectiveness?

Firstly, proximity makes easier comparisons between cases and their modus operandi. If all the offences occur in the same police area, the investigators are generally aware of the other similar cases. By contrast, communication can be very limited between different police services especially for the most common offences. This comparison is also easier with temporal proximity. The reason is not directly connected with communication but more with memory, the capacity to remember similar events in the past. It will be easier to remember a similar modus operandi if the previous offence occurs only some days or weeks ago.

However, crime officers can have a more proactive behaviour by monitoring possible linkages for typical offences. In the context of an exploratory research, the spatial and temporal proximities are two dimensions of the hyperspace of information (Turton et al., 2000) with respect to which data mining can search for nearby events. By blocking a range of space and time, the police may have a systematic comparison of the modus operandi of nearby events.

In the cases described above, the linkage is based on similar modus operandi while the spatio-temporal proximity facilitates their comparison. However, the temporal and spatial proximities of crimes can be themselves important criteria for the linkage.

The impacts of geographical and temporal proximities in linkage have been studied for offences such as serial burglaries, serial car thefts or serial sex offences (Bennell and Canter, 2002; Bennell and Jones, 2005; Goodwill and Alison, 2006; Tonkin et al., 2008; Grubin et al., 2001 cited in Markson et al., 2010). The analysis of pairs to link crimes showed that there was greater consistency in the spatial and temporal similarities than those in the modus operandi (Goodwill and Alison, 2006; Grubin et al., 2001). In order to estimate geographical proximity, studies mainly used the mean inter-crime distance. Studying temporal proximity, Goodwill and Alison (2006) showed that the day interval was a better indicator of crime linkage than the time of crimes (hours).

### **4. Unit area issue and its impacts on factors**

The problem of the modifiable unit area (MAUP) is well-known in geography where it is considered as a source of bias in multiple spatial analyses (Openshaw,

1984; Cressie, 1996; Unwin, 1996). Geographic profiling obviously is not exception to this issue. As soon as point data – occurrences or measures - are aggregated by postcode areas or police precincts for instance, the selected boundaries affect the meaning and the significance of the figures. This section does not develop deeply all the impacts of the MAUP but highlights the influence it has on already discussed factors.

The most frequent inconsistency is a scale issue: the unit areas are too small or too large related to the phenomenon under investigation. For example, police crime statistics aggregated at the municipal level make impossible the identification of crime attractors or generators at the street or city-block levels. The population potential computed for each unit may hide great variations inside the area. In the same vein, measuring the overall attractiveness of a city can hide significant spatial variations between its different neighbourhoods. Recent studies advised to choose a small spatial unit (Weisburd et al., 2009), especially for studying the attractiveness of crime places (Bernasco, 2010).

However, they do generally not propose to consider simultaneously several levels to evaluate place attractiveness. They neglect the fact that a place may have different attractive influences in function of the level of observation. A city with potential attractive functions, at a national level for example, has also ordinary functions for which the attractiveness is reduced to local vicinity. For example, the common bar institutions, located outside the most frequented neighbourhoods probably do not have a greater attractiveness than those located in smaller, medium sized cities. A first advice is then to favour multi-scale analysis for the evaluation of this factor.

Secondly, the spatial partition forced / imposed by the use of unit areas may conflict with a phenomenon which is intrinsically spatially continuous. The distance decay model used in geographic profiling is precisely a spatially continuous model (in an isotropic or anisotropic space) which can hardly be correlated with figures aggregated in arbitrary areal units. For example, the influence of nearby units may be important (Bernasco and Block, 2011) when the units are small in comparison with the length covered by the distance decay (smooth slope). In addition, arbitrary space discretization generates a segmentation of information. Thus, a police officer investigating a crime committed on the edge of a spatial entity and who is not aware of similar crimes in a neighboring entity, will tend to move the assumed anchor point towards the centre of the entity under investigation (Rengert and Lockwood, 2009).

There is also concern about the impact of unit size on the calculation of rasterized surfaces. Thus, the accuracy of the likelihood surfaces is affected by the over-or

underestimation of distances depending on the position of crime sites in cells superimposed on the study area.

A second advice should be to pay attention to the possible influence of close units when small unit areas are chosen. This influence should be taken into account in the modelling with a kernel density estimator (Levine, 2004).

### C. Integration of the temporal properties to complete spatial factors

The previous section revealed that the temporal dimension is extremely linked to the spatial factors conditioning an effective geographic profile. Capone and Nichols (1975) already observed that time impacts the average distance to crime. Crime generators during shop opening hours are different from those during the night. Spatial proximity is useless without the temporal one.

Introducing temporal information presents several issues. First, the information is often missing, police officers failing to record the temporal elements (Brantingham and Brantingham, 2003). Besides, when recorded, it is often imprecise as the victim is not capable to report an accurate time of when the crime occurs because of his absence (burglary) or because of the choc (rapes). Thereby, the precision about the moment of crime varies, among others, in function of the offence type with better precision for robbery, assault or street offences than burglaries (Ratcliffe, 2002).

However, even when it is imprecise, temporal information may still be useful. The temporal dimension is multi-scale: from the years to the seconds, with several dichotomies organising people activities: night/day, working/vacation days, or even categories such as the days of the week, the hours, etc. Chainey and Ratcliffe (2005) describe several temporal categories: the moments, the duration, the structured time (hours), time as a distance and time span, and all those categories can be used in an investigation. The following sections analyses successively several temporal categories that may bring new insight on the offender's spatial behaviour. It details the relationship between the offender's crime locations and anchor point thanks to the introduction of the temporal dimension.

#### 1. The Moment of crimes: relation with offender's activities, potential targets and absence of guardianship

The moment when crime occurs is influencing our understanding of the offender's decision process (evaluation of risks, costs and benefits according to the rational choice). From the temporal point of view, place properties are not static. They evolves over long time periods but also according to the hourly rhythm of human activities. Time influences the three components of the crime described by the routine activity theory:

the presence/absence of offender, potential target and capable guardian (Cohen and Felson, 1979). As "the relevant actors – victims, offenders, guardians, and place managers – adjust their relative densities over time and around specific places, the opportunities for crime shift and coagulate" (Ratcliffe, 2010:15).

From the perspective of profiling, the timing of the crimes informs police investigators about the offender's activities or constraints. Indeed, the facts taking place as well during the day as during the night will rather be liaised with someone unemployed, with a rambling lifestyle. By contrast, the facts occurring on very small time slots could mean more constraints for the offender such as work with a regular schedule, a family to whom he must justify his absences, etc.

Potential victims are also changing through time. The concepts of crime attractor and generators are particularly closely related to the temporal dimension (Brantingham and Brantingham, 2008). Depending on day or night, a location can be either a crime generator or a crime attractor or a neutral place for the same crime type. Supermarkets or commercial locations are crime generators only during the day for pickpockets. A very busy place during the day may become completely deserted at night, for example in business districts, and vice versa for residential areas. This results in differences in the presence of guards during the day.

The integration of temporal dimension is then crucial when analysing the pattern of crime locations in order to evaluate if they can be considered as neutral so that the distance decay could have some positive impact.

#### 2. Spatio-temporal clustering

Among conditions enumerated by Rossmo (2000), the presence of a stable anchor point is generally required for any GP methodology. This condition, if difficult to validate, can be better estimated with the integration of the temporal dimension.

Indeed, the analysis of spatio-temporal clusters is a first indication of multiple anchor points or different modes of transportation. The offender or victim's mode of transportation can vary according to the days of week. As an example, a young offender is studying in one city, leaving there during the week, travelling mainly with public transportations. During the weekend, he comes back to his parent's house in the countryside. He travels there only as a pedestrian. By dividing the series into two sub-series (week and weekend), the two spatial patterns around his two anchor points will be clearly identified. Besides, the mean inter-crime distances for the weekend pattern will probably be shorter than the week one. Besides, the clustering can be explained by the choice of victims such as a rapist operating in the vicinity of bus stops in the morning hours but never during the weekend given the lack of victims.



### 3. Chronology

The chronology of events allows to precise another of the Rossmo's assumption: the presence of several crime locations. As it was described above, Lundrigan and Canter (2001) studying serial murders, insisted on an interesting temporal aspect: the presence of an emotional "cooling-off period" between each crime as opposed to the mass or spree type, in which all crimes occur more or less simultaneously. If all the crimes occur in a few hours, there is a high probability to face one or multiple offenders commuting to the areas. The several locations are only steps in the same journey-to-crime. Several crimes locations are then not enough; they must also be separated in time to build a likelihood surface based on multiple journeys-to-crime.

This cooling-off period can be days, weeks or months. A smaller number of days between crimes seems to be correlated with a commuter behaviour (Paulsen, 2007). By contrast, if crimes occur during several months or years at locations not far from each other, the conditions of stable anchor point and small journey-to-crimes will often be satisfied. However, longer time periods increase the probability of a moving anchor point.

If an offender doesn't go back to his residence after a crime, conducting a circuit path, the chronology indicates the direction/sense of this path. It provides then information about his provenance.

The relationship between distances travelled by the offender and the chronology of events is reviewed by Snook et al. (2005) for serial murders. Both a decrease and an increase in distances from home base to crime locations have been observed (Godwin and Canter, 1997, Rossmo, 2000) and find a logical explanation. An increase in travelled distances could be explained by the fear to be recognised, leading the offender to travel further from his anchor point. A decrease would be the result of a confidence-building, the offender taking more and more risks.

*"Closely associated with series chronology is the belief that serial offenders live in closer proximity to their first crime location than their subsequent crime locations (Canter, 1994, Canter and Larkin, 1993, Warren et al., 1995)" in (Snook et al., 2005: 150). A more steady distance decay to home should then be observed from this crime location. But even this believed is not always observed. While Rossmo (2000) found that 41% of serial murders commit their first crime at the nearest location from home, the closest offence location corresponds to the first one for only 18% of the serial rapists studied by Warren et al. (1995)*

Besides, in an operational perspective, police investigators can never be sure that the first offence recorded in the series was the first committed by the offender.

Some victims may have not complained their injury. Or even, the offender was maybe already involved in other criminal activities before which had some influence on its knowledge of crime locations.

### IV. DISCUSSION: A DECISION TREE SYNTHESIZING CONSTRAINTS AND FACTORS.

A decision tree synthetises the relationships between the constraints and factors discussed in the paper and the usual conditions required to build an effective likelihood surface in GP. The tree is a tool for investigators confronted to a new investigation for which it should be decided to build or not the geographic profile.

It should be read from top to bottom. At each step, the investigator can check which conditions (italic) depend on the constraint or factor. The constraints of the premeditation and the seriousness of the offence have a binary reading while the factors have a more gradual impact on the application of GP. Premeditation is linked to a rational choice for which a single anchor point and short distances are more frequent than in opportunistic situations. Violent crimes are preferred to the other offences for the resources spent in linking such crimes and to meet the higher expectancies of the victims.

At the third level of the three, decisions must be taken with regard to different components: the type of crime, the offender's properties and the spatio-temporal pattern of the crime locations. For example, serial rapes and sexual assaults are the crime for which an application of GP generally presents the best conditions: small journeys-to-crime, easy determination of multiple offenders by contrast to arsonists who are often acting in groups. The application to serial murders is also possible if some categories such as the extremists or terrorism are rejected. For the spatio-temporal pattern, neutral places are crucial for applying distance decays functions but place attractiveness should always be evaluated for a specific moment.

### V. CONCLUSION

This paper had for objective to identify the constraints and factors enabling the computation of an effective geographic profile, with the specificity of focusing only on the elements that could be available during an investigation. It aimed at filling the gap between the inductive demarche of environmental criminology and the studies on the journey-to-crime and the hypothetico-deductive, operational procedure followed by geographic profilers.

The article was based on the conditions, mainly defined by Rossmo (2000), necessary for the implementation of likelihood surfaces with a particular attention to the

respect of the distance decay and uniform distribution of potential targets around the anchor point, two conditions closely linked to the geography of the crimes.

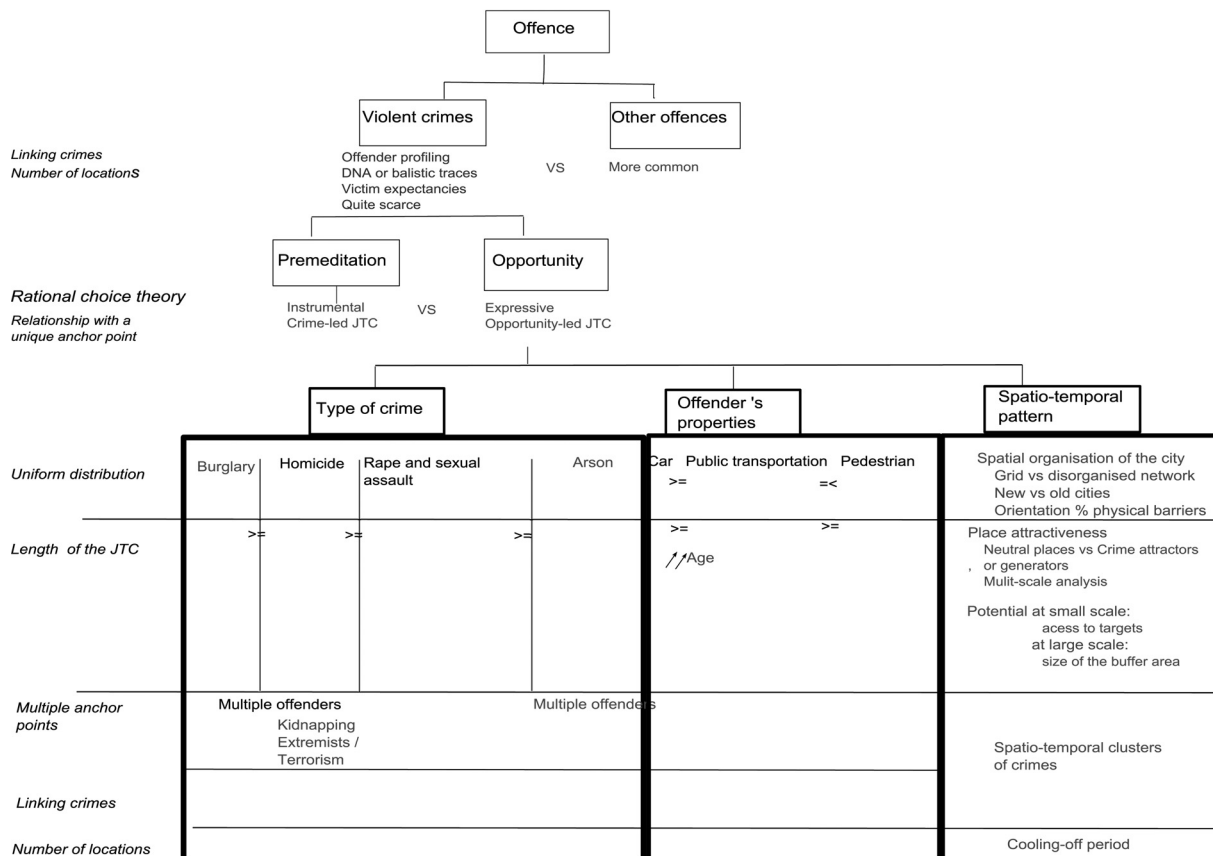
With regard to the constrains, premeditated violent crimes committed by a single offender are required to build a geographic profile on the hypotheses of a rational choice, unique anchor point with a sufficient number of linked events. Concerning the factors, the spatio-temporal pattern of the crime series plays has a major influence on all the conditions defined by Rossmo. Geographic concepts such as place attractiveness, population potential, spatio-temporal proximity have to be evaluated for each crime location in order to estimate which condition risks to be rejected. Especially, neutral places associated, by definition, with lower attractiveness should be distinguished from crime generators and attractors in the implementation of likelihood surfaces. A distance decay function with a steepest slope should be applied on the neutral places. Temporal aspects are extremely connected to the spatial behaviour. The moment of crimes informs the investigators on the offender's constraints and helps to qualify places as attractive or not. Spatio-temporal clusters may be associated with sub-patterns around different anchor points. The chronology is an indicator of the stability of the

anchor point.

This decision tree provided as a synthesis should be considered as a tool for evaluating the risks of an ineffective geographic profile. Investigators may still develop an alternative approach to the classical likelihood surfaces that does not require the unmet condition. The uniformity may not be required for Bayesian approaches that include origin-destination matrices (Levine and Lee, 2009). The distance decay effect can be replaced by a minimization of travelled distances or departure time (Trotta, 2012, Trotta et al., 2011). The investigators will have to choose for the appropriate spatial hypothesis and develop a corresponding suitable research methodology. Until now, such ways of modelling that do not rely on domocentricity have been less studied (Canter and Youngs, 2008) and still need to be tested on large sample of data.

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**Figure 2:** A decision tree to determine the optimal conditions for building a geographic profile.

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