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Introducing spatial configuration in crime count models[1]

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Abstract

The main techniques used for quantitative analyses of urban crime can generally be divided into three categories: descriptive studies of crime dispersion over a specific urban area without any substantial statistical modeling, traditional statistical spatial models whose normality assumptions do not hold and count models which do not take into account the spatial configuration of the urban layouts. In this work we discuss how configurational components can be introduced in the count data modeling of crime illustrating our point with a case study centered on a highly populated area of the City of Genoa on three crime typologies. The statistical modeling of crime at street level is performed using count models which include the usual economic and socio-demographic variables, complemented with a set of configurational variables, built using the techniques of Space Syntax Analysis, in order to include, among the regressors, the graph complexity of the urban structure. The configurational variables included in this model are statistically significant, consistently with the criminological theories stating that the urban layout has a role in crime dispersion over a city and their use among the set of regressors, substantially improves the overall goodness of fit of the models. The configurational variables herein introduced add an implicit spatial correlation structure of crime to the models and give new and useful information to Municipalities to interpret how crime patterns relate to the urban layout and how to intervene through the means of urban planning to reduce or prevent crime.

Keywords: *Urban Crime Analysis · Count data models · Space Syntax · Segment Analysis ·*
Jel Classification: *C83, O18*

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1. Introduction

Criminology has, since long, identified two vast fields of study: the socio-economic determinants of crime and the geographic or spatial features of areas which are scenarios of crime. The Department of Sociology of the University of Chicago is largely responsible for developing the Social Disorganization Theory (Thomas, 1966). By studying the vast growth of the city of Chicago between 1860 and 1910, they noticed that urban areas were more crime-prone than rural ones. Moreover they found out a connection between crime and several urban issues like poverty, racial heterogeneity and residential mobility, all leading to the weakening of social control and the disintegration of formal social organizations (Paulsen and Robinson, 2009). On the other hand, the interest in geographic criminology began during the 19th century in France and in Belgium after the publication of the first geographical map of crime. In 1829 Michel Andrè Guerry and Adriano Balbi published a map representing the distribution of crime over the Departments of France between 1825 and 1827. This preliminary study was followed by that of the Belgian statistician and astronomer Quetelet in 1842 and by a number of studies in the Netherlands (William Greg), England and Wales (Rawson R. Rawson, Joseph Fletcher, John Glyde, Henry Mayhew) and in Italy (Cesare Lombroso) (Paulsen and Robinson 2009; Weisburd *et al.*, 2009). The two fields have been somewhat connected since their early stages. Quetelet himself was specifically interested in the reasons for geographic patterns that emerged while mapping crime rates in French regions. Most of the literature concerning ecological theories of crime and social disorganization (or collective efficacy, which is the conceptual opposite of social disorganization) is based on the assumptions that crime is not uniformly distributed in space and that social and spatial factors interact one another generating the differences in crimes dispersion.

Between the 1960s and the 1970s several authors (e.g. Jacobs, 1961; Newman, 1972; Jeffery, 1971) developed analytical frameworks of crime and insecurity in the urban environments focused on spatial and functional features of the built environment. Their work, which is globally labeled as the Ecological Theory of Crime is, in fact, the combination of very different approaches (Crime Prevention Through Environmental Design - CPTED, defensible space, eyes on the street, etc.).

These ideas paved the way, during the 1980s, to the development of situational crime prevention (Clarke 1983, 1992, 1995). According to the followers of the situational crime prevention, in order to reduce the number of crimes, it is necessary to reduce the opportunities of committing a crime, because "opportunity makes the thief" (Felson and Clarke, 1998). These ideas led crime analysts to increase the attention for urban design details (such as street furniture, street lighting, pedestrian pathways, housing design, visibility from the street and of the street) and to a deep study of the spatial configuration of the streets conducted through the Space Syntax Analysis (SSA) (Hillier, 1988). SSA was initially conceived by Prof. Bill Hillier and Julienne Hanson in the 1970s and 1980s at the Bartlett University College of London as a theory to analyze small environments and their configurational features. This discipline studies, through quantitative measures, the configurational properties of urban space (Hillier and Henson, 1984). Thus it permits to identify patterns and structures which influence the development of activities in space, in particular movement and land use (Hillier and Sahbaz, 2008, Hillier *et al.*, 1993). Since movement and land use are thought to be linked to crime, SSA was used in the development of the CPTED proposed by Jeffery (1971). Thanks to the increasing number of measures used in the Space Syntax Analysis, it soon became possible to compute the relative degree of accessibility, connection and integration of each street in its urban network, and to numerically index a large number of properties of the urban environment (Hillier and Sahbaz, 2008). Among the others, Beavon, Brantingham and Brantingham (1994) analyzed the street structure and its dependence with crime volumes: they found that streets with many twist and turns have higher crime rates.

During the last thirty years, a new theory on the spread of crime through urban spaces emerged. According to the Routine Activity Theory (Cohen and Felson, 1979) the number of crimes increases if the number of opportunities for criminals rise and if society lacks an adequate surveillance against crime; indeed crimes are often committed in places where victims and offenders hold their routine activities, for example work, leisure or social interaction, and where they satisfy their basic needs (Eck and Weisburd, 1995). This theory focuses on space because it is considered an explicit determinant of human actions, including committing offences. Some empirical studies are in favor of this theory: Cohen and Felson (1979) used Routine Activity Theory to explain the increase in the number of crimes in American cities; for instance, they pointed out that, with more women working, a larger number of houses were empty during daytime and this fact led to the rise in the number of robberies increasing the vulnerability of suburbs. Roncek (1981) found out that, in Cleveland, streets with schools and bars are highly crime dense, while Rice and Smith (2002) and Smith and Clarke (2000) identified the places near commercial stores as particularly risky. In this context, some studies on the relationship between crime and transports have been developed by Smith and Clarke (2000) and by Block and Davis (1996): they conclude that the structure of the public transport system can influence the number of crimes committed: higher numbers of crimes are recorded near stations and bus stops. As a matter of fact, during recent years, a new interest for a combined study of socio-demographic and spatial factors in the analysis of crime has emerged (e.g. Weisburd *et al.*, 2009). In fact, although crime mapping is certainly the most immediate way to obtain quick information on the criminal incidence in an area, it is interesting to study the relationship between urban crimes and the economic, socio-demographic and spatial features of the study region. Indeed, the study of crime in the context in which it happens could bring to the identification of both global and local risk factors, helping local governments in drawing up policies for Urban Safety. Chih-Feng Shu (2000) provides empirical evidence for skepticism on the idea of "territoriality" and "defensible space" put forward by Newman (1972): he suggests that, other things being equal, property crimes tend to cluster in those globally or locally segregated areas. In detail, particularly risky areas can be found in cul-de-sac footpaths and rear dead end alleys, but also in those segregated short cul-de-sac carriageways which Newman considered to be the key places where local surveillance should be increased and casual intrusion by non-residents excluded. Hillier (2004), discussing the work by Chih-Feng Shu (2000), concludes that in Space Syntax Crime Analysis, spatial factors are relevant and that they operate both at a global and local level. More recently, Sinkiene *et al.* (2012) discuss the relationship between crime and urban planning presenting also the results of an empirical research conducted in the city of Vilnius: the aim of this study is to identify, with the use of ASA, the most vulnerable open public spaces of the city. A number of empirical papers have been produced over the years, investigating the capabilities of SSA to interpret crime risk. Hillier and Sahbaz (2005) compare residential burglary and robbery in the street network of a London borough using SSA. Nubani and Wineman (2005) use it to describe the geographical location of four types of offense behavior in the city of Ypsilanti, Michigan: breaking and entering, larceny, vehicle theft and robbery. Friedrich *et al.* (2009) explore spatial characteristics of urban environments in relation to the occurrence of antisocial behavior. Monteiro (2012) compares the statistics on theft and robbery in Joao Pessoa, Brazil, with the configurational qualities of the spaces where they take place.

Due to the complexity and the inherent multidisciplinarity of research on crime and place, it seems unsatisfactory that the main approach used by the police and by local governments to organize crime prevention policies and actions is crime mapping. Modern crime mapping techniques permit to visualize crime events on a map in order to analyze the distribution of crimes in space and to identify crime incidents patterns using different types of maps, such as point maps, line maps or areal maps (Boba, 2012; Weisburd and McEwen, 2010; Paulsen and Robinson, 2009). The aim of crime mapping is to geographically locate criminal occurrences in order to detect hot spots and to organize efficiently police interventions and patrolling duties in these crime-concentrated areas through the use of a Geographic Information System (GIS) (Chainey and Ratcliffe, 2005; Murray *et al.*, 2001). As such, crime mapping is largely a-theoretic and provides information that has operational value almost exclusively for the police. The statistical models used to complement crime mapping with analytical tools are various (see, for an updated review, the recent work edited by Piquero and Weisburd, 2010) but can be classified in two main categories: count models which do not take into account any spatial correlation among data (e.g. MacDonald and Lattimore, 2010) and linear models which introduce the specification of a spatial structure of data (e.g. Bernasco and Elffers, 2010) and which require assumptions which are not generally suitable for the count nature of criminal data. In this work we propose a way to analyze the spatial distribution of crime as it relates with the features of space itself and those of the local populations, expressed through sets of variables suggested by the scientific literature (Wilsem, 2009; Nubani and Wineman, 2005). In particular we use statistical count models to express the relationship between crime occurrences and the set of contextual variables (economic, socio-demographic and spatial configurational), all collected at street level. The use of configurational variables lets us introduce in the traditional count models a component which implicitly describes the spatial structure of urban layout. Although it is not possible to infer a precise causal dependency between crime occurrences and most of the variables, a positive or negative correlation between them can still be part of a model describing which elements of the context are more likely to be associated with high levels of crime and which of them are the best candidates for a direct action from local governments, police or relevant local organizations. As such, the model proposed should be thought of as the foundation of an analytical framework that can support the decision making process of relevant local institutions on a regular basis and that can be methodologically extended in the ways that will be specified in the final remarks.

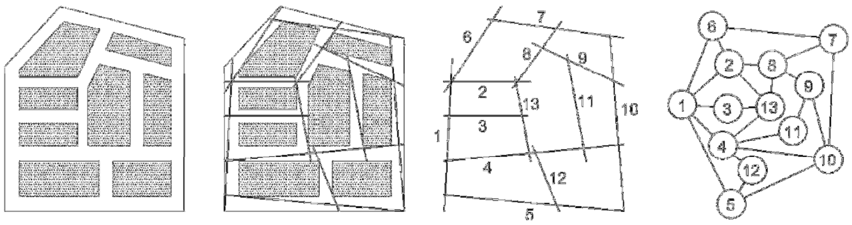
2. Methods

Configurational Analysis and other data available

Configurational analysis consists of a number of methods to describe, in quantitative terms, both the links connecting the spaces through which people move in the urban environment (Hillier *et al.* 1993) and the pattern properties of those spaces (Penn *et al.* 1998). The urban layout of a city and, specifically, its system of roads and public spaces intertwining the buildings, can be thought of as a network which can be represented as a non directional graph (see, among the others, Balakrishnan 1997 and Wasserman and Faust, 1994) and then analyzed either adopting the standard metrics proposed in the vast literature of graph theory or formulating new ones, specifically designed to analyze space and human behavior in space. The basic and earlier forms of configurational analysis (i.e. SSA) convert the network of roads and open spaces in an axial map of the fewest and longest straight walkable lines (axial lines) that cover the whole grid and their intersections. The axial map is then interpreted as a graph where, counter-intuitively, each road, or part of it, is intended as a node of the graph and each crossing between roads is an edge (Penn *et al.*, 1998). Figure 1 shows this three steps procedure. From left to right it is possible to see a simple urban layout, the conversion of its open spaces into an axial map, the axial map whose elements are numbered sequentially and, finally, the undirected graph correspondent to the axial map. This dual representation of the urban layout (e.g. Porta *et al.* 2006), makes it possible to quantify the topological properties of the whole network of streets, squares and alleys allowing the study of their relationship with other more conventional quantitative variables. In fact, when added to the model, the variables originated from the configurational analysis are expected to provide an accurate picture of the natural movement of pedestrians (Hillier *et al.* 1993; Hillier 1996), the use of space (Chang and Penn 1998), the spatial segregation (Cutini, 2009; Vaughan, 2007), the vehicular traffic (Dalton and Turner, 2003; Hillier 1996; Penn *et al.* 1998), the distribution of commercial activities (Hillier, 1997) and, in broader terms, a representation of relative non-metric distances (Batty, 2004; Dalton *et al.*, 2003; Hillier and Hanson, 1984; Hillier 1996). The measures proposed in the SSA literature are very numerous (e.g. Hillier 1996) and among the others we recall, as regressors of the subsequent statistical models, connectivity, integration and choice. Although these measures are deeply inspired by well known graph theory measures, they are variations of them and we think it is useful to give a definition of these measures comparing them with the original measures of graph theory.

Connectivity, one of the main measures of graph theory, is built on the idea of reachability between pairs of nodes and aims to identify those nodes in the graph (i.e. those roads in the urban network) which are critical for the cohesiveness of the graph. A graph is cohesive if, for example, there are many nodes that are connected one another, and, therefore there are numerous alternative paths on the graph to move between pairs of nodes. In urban map terms, this means that a city is cohesive if there are many alternative paths that can be followed to move from one

Figure 1 – Dual representation of urban map according to Space Syntax axial decomposition.



street (a node) to another (another node). On the contrary, if a graph is not cohesive it is vulnerable to the removal of a few nodes or edges which connect two subgraphs which would be, without the connecting nodes or edges (called bridges) two disconnected graphs. The (node) connectivity $k(G)$ of a graph G of g nodes is the number of nodes n_i (i = 1,2, ..., g) that must be removed to make the graph disconnected. If the graph is already disconnected $k(G)$ = 0, if the graph contains one cut point $k(G)$ = 1 and it is sufficient to remove one single node to leave the graph disconnected and so on. This global measure of connectivity (see among, the others Wasserman and Faust, 1994, pages 112-117) is made on the whole graph and it is not a local measure of connectivity. The connectivity measure used in SSA ($C(l)$) has a local meaning as it counts the number of edges that are lost if the l-th node in the graph is deleted (i.e. is the nodal degree measure d of graph theory). Although not corresponding to the global measure $k(G)$ it maintains a strong meaning in terms of cohesiveness of the urban network. In fact if all the nodal degrees are equal, the graph is said to be d-regular but their variability denotes that the nodes differ in "activity" or role in the graph structure. The nodal degree, or the connectivity measure according to the SSA notation, is evidently a relevant element to evaluate nodal centrality.

The second SSA measure cited above, integration, is based on graph theory's closeness centrality and focuses on how close each street is to all of the others. The idea of integration is that a node, and therefore a street, is central in the graph if it can be quickly reached from most of the other streets and, consequently, these streets represent the main ways of communication inside the town. The meaning that we can give to "closeness" between streets may vary, but as general rule, the global distance between any couple of nodes (n_i, n_j) can be defined as the smallest number $d(n_i, n_j)$ of edges between them, regardless of the sharpness of the turns and SSA refers to this measure as "depth" or D. In order to summarize all these distances between node n_i and all the other nodes of the network, a unique index can be created. In graph theory, the simplest measure of the distance between one node and all of the others is the one proposed by Sabidussi (1966), that is, the inverse of the sum of the distances from node n_i to all the other nodes, equaling, at a maximum, $(g-1)^{-1}$ if the node is connected to all the other nodes in the graph with distance $d(n_i, n_j) = 1$, and attaining as minimum the value zero in its limit whenever some nodes are not reachable from node n_i. SSA modifies this measure in order to compensate the effect that the number g of nodes in the network has on it. As a first step SSA defines the mean depth using the same aforesaid distance criterion between nodes:

$$\bar{D}(n_i) = \frac{\sum_{i=1}^{g} d(n_i, n_j)}{g-1},\ i \neq j \qquad (1)$$

The value of (1) is not indifferent to the graph size as it increases when g grows and therefore its normalization according to the graph size is required. This normalization has been introduced by Hillier and Henson (1984) who specified a measure called relative asymmetry (RA) which compares the depth of a graph from a particular node with the deepness and shallowness it theoretically could have. If the node is connected to all the other nodes in the graph, (1) equals 1 as a minimum and *g*/2 as a maximum when the graph looks like a unilinear sequence away from that node. Therefore it is possible to define the following measure of integration:

$$Int(n_i) = \frac{2(\overline{D}(n_i) - 1)}{g - 2} \quad (2)$$

Theoretically, the integration measure expresses the cognitive complexity of reaching a street, arguing that the easier it is to reach a street, the more often it should be used for movement (mainly pedestrian) inside the city. Although the evidence towards this interpretation of the measure is still under discussion (e.g. Turner, 2007), as it is biased towards long, straight streets that intersect with numerous other streets, there is a relevant number of publications which present a significant correlation between integration and pedestrian flow (Hillier *et al.* 1993; Hillier 1996).

The third SSA measure herein discussed, choice, corresponds to the betweenness centrality measure of graph theory (Freeman 1977). In graph theory, the interaction between two non adjacent nodes depends on the other nodes, especially the ones that lie on the path between the two. These intermediate nodes may have a potential control on the interactions between the two nonadjacent nodes. Therefore it is possible to define a betweenness centrality, or strategic centrality, measure of each node (or street) whenever it lies between two nodes on their geodesic path. In practice, defining $\sigma_{jk}(i)$ as the number of paths linking nodes n_k and n_j containing node n_i for all the distinct indices *i*, *j* and *k* and σ_{jk} the number of all the geodesics linking nodes n_k and n_j, the SSA Choice measure is given by:

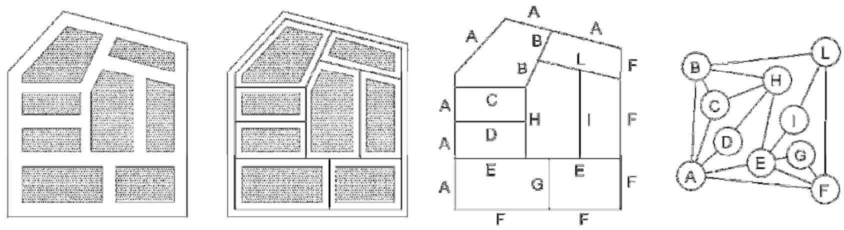
$$Ch(n_i) = \sum_{j<k} \frac{\sigma_{jk}(i)}{\sigma_{jk}} \quad (3)$$

for *i* distinct from *j* and *k*.

An additional spatial measure that we use in the subsequent models is the length l_i of node n_i. This is not a configurational measure as each node is a point in the graph whereas l_i is a physical attribute, the metric length, of the street which node n_i is the dual representation of.

Axial analysis remains one of the fundamental components of space syntax but recently a number of proposals have been made to overtake some limitations that are now evident. First of all, and primarily relevant for this work, axial analysis has been developed in an urban planning framework, without fully taking into account the idea that the measures taken from the graph theory may be used in conjunction with other variables in complex statistical models with a substantial lack of formal specification of the axis as a statistical unit on which one could measure multiple phenomena at the same time. Moreover it has been noted (see, among the others, Turner, 2007) that the resulting axial representation of the city may be strongly dictated by some subjective choices made by the cartographer such as the starting street for the axial decomposition procedure of the urban layout or the inclusion of trees for the occlusion of the straight walking lines cited before, choices which could bring to similar but not identical results for SSA. Recently there have been many proposals for variants of the SSA measures with the main goal of computing them directly on GIS systems instead of using axial maps (e.g. Cutini *et al.* 2004). This, along with the more statistically oriented nature of GIS environments in comparison to SSA software, broadens the opportunities of using these measures in a new statistical perspective. One of the most interesting variations of SSA is the Angular Segment Analysis (ASA) which breaks axial lines into segments and then records the sum of the angles turned from the starting segment to any other segment within the system (Turner 2001; Dalton 2001). The lines of the original network are divided into segments according to their intersection points, and the distance between any couple of segments is measured not simply in terms of number of turns dividing them, but as the cumulative sum of the angles of each turn (Dalton and Turner 2003; Hillier and Iida 2005; Turner 2000). All the SSA measures introduced before can be modified consequently obtaining the angular connectivity, angular integration and angular choice measures. Relevantly to this paper, angular segment analysis breaks down longer, straight roads, providing the framework for a finer grained analysis and is largely compatible with general-purpose road graphs (Turner 2007) of the same kind that is commonly used by local governments in their GIS. We had the opportunity to work on the official shapefile of the Municipality of Genoa in Italy which contains the geometries of the whole urban graph but also which many administrative databases at street level refer to. The problem we had to face, from a merely technical point of view, was the one of analyzing the configurational characteristics of a GIS layout at street (and not segment) level in order to make administrative data and ASA variables measured on the same set of statistical units. The general logic we followed was the one of working not on axes but on straight road-center lines using default GIS features and coherently with what has been suggested by Turner (2007) for ASA. We acquired this road-center lines graph, that is an excellent approximation of the ASA segment map, in the open source software UCL Depthmap, created in 1998 by Alasdair Turner at the University College of London and we computed the ASA measures on it. The resulting dual graph is therefore the one shown in Figure 2 which should be interpreted in a similar way of Figure 1.

Figure 2 Dual representation of urban map according to urban decomposition according to the street name approach.



In order to use these measures in the following statistical models, we had the problem of joining them at the same street level used for the socio demographic variables and we used two approaches.
Given a road r_i, divided into k segments s_{ij} (j = 1, …, k), we computed the Integration and Choice measures of each road as their weighted means using lengths l_{ij} of the segments as weights:

$$ASA(r_i) = \frac{\sum_{j=1}^{k} ASA(s_{ij}) l_{ij}}{\sum_{j=1}^{k} l_{ij}} \qquad (4)$$

where ASA(·) indicates any of the two ASA measures relative to the i-th node described ahead. Relating Connectivity, the main problem concerned the fact that each street is made of various segments, a large part of which are connected only with other two segments of the same toponym. Therefore, the connectivity measure of each street can't be directly used on GIS oriented maps in the form it is defined in ASA. In fact it results to be largely overestimated as it includes all the angles between segments of the same street, i.e. curves and not only crossings. Moreover the measure is strongly correlated with road length: long winding roads without crossings resulted to be among the ones with the highest connectivity measure. As we are interested in a inter-street and not a intra-street connectivity we measured connectivity only among the segments of different toponyms obtaining a measure that, to be named differently from the ASA connectivity measure, we called Permeability. Permeability of road n_i (or its dual correspondent, the node n_i) is therefore the sum of all the angles among the segments of road n_i and all the segments of the other roads incident to them divided by the whole length of road n_i. In this way, we generated a dataset of configurational measures integrable with the socio-demographic and economic variables acquired from the Municipality of Genoa administrative databases.

Socio-economic data

The non configurational data used in this work derive from two databases owned by different institutions the Municipality and the Prefecture of Genoa, which cooperated to implement a statistical model to interpret crime patterns in a highly populated district of Genoa (Marassi: 43,084 residents of which 11,802 over 65 years old and 4,239 foreigners, 846 shops, 1 soccer stadium and a surface of approx. 7 km^2 with 83 different street names).

The first dataset contains the complaints collected by the local Carabinieri Station from 1st January 2009 up to the 27th of July 2010. In Italy, complaints are collected by multiple police forces, five of which are federal agencies (Polizia di Stato, Carabinieri, Guardia di Finanza, Polizia Penitenziaria and Corpo Forestale dello Stato). Of course, not all the criminal events relating the study area in the period of interest have been collected by the local Carabinieri Station but a unique database of complaints was not available for this research. Moreover, not all the complaints correspond to actual criminal events and not all the events are reported to the police forces for various and untraceable reasons. Finally, part of the complaints available in the original database related events happened outside from the study area or in places which we could not geolocalize (missing address or buses, for instance). Out of the original 4,095 complaints, we could effectively include in our analysis 1,643 of them, all localized at street level. Table 1 gives a description of the crimes distribution on the 83 streets dividing the events according to a simplified version of the highest level of crimes classification used by the Italian Ministry of Interior: violent crimes (e.g. attacks and murders), predatory crimes or crime against property (thefts, robberies, muggings) and arson and criminal damage (actions of vandalism). Table 2 counts the number of events referred to the four and to the ten roads of each category which recorded the highest numbers of occurrences. Looking at these statistics, consistently with various empirical findings (e.g. Eck and Weisburd 1995, Taylor 1997), it is evident that most of the streets present low levels of crime (a relevant percentage of which with zero events recorded) whereas a few streets resulted to be the scenario of most of the crimes.

Table 1 - Number of streets per crime events span and corresponding descriptive statistics.

	Total Crimes		Predatory crimes		Arson and criminal damage		Violent crimes	
	streets	%	streets	%	streets	%	streets	%
0	11	13%	15	18%	24	29%	58	70%
1 – 10	38	46%	47	57%	40	48%	25	30%
11 – 20	10	12%	10	12%	5	6%	0	0%
21 – 30	10	12%	2	2%	8	10%	0	0%
> 30	14	17%	9	11%	6	7%	0	0%
Total	83	100%	83	100%	83	100%	83	100%
Mean	19.79		10.81		8.43		0.55	
Var	928.63		344.16		154.17		1.39	
Max	155.00		76.00		74.00		6.00	
Crimes	1,643		897		700		46	

Table 2 - Crime occurecies in the four (Top 4) and ten (Top 10) roads with the highest numbers of crime facts.

	Total Crimes		Predatory crimes		Arson and criminal damage		Violent crimes	
	streets	%	streets	%	streets	%	streets	%
Top 4	317	34%	301	34%	162	23%	16	35%
Top 10	581	62%	553	62%	335	48%	28	61%

Our goal is to express the frequency of crimes as a function of the configurational variables discussed in the previous section along with the socio-economic variables proposed over the years by the criminological theories. The Territorial Office of the Municipality of Genoa provided the second set of variables including: residents per gender, age interval (0-18, 19-40, 41-65, over 65) and nationality and the number of shops per size grouping and typology of merchandize. All these data were available at street name level. No economic data about yearly income of residents or land register house value were available due to privacy reasons for the too high territorial detail of data. For the same privacy reasons, data are herein presented in aggregate form, without any particular mention of street names.

The set of variables that we use as regressors in the statistical model can be divided into three categories: configurational, socio-demographic and economic variables.

The four configurational variables are the street length (STREET_LENGTH) computed on the urban graph and the three configurational measures PERMEABILITY, CHOICE and INTEGRATION.

The main socio-demographic variable used is the number of residents per street (RES_TOT). In the subsequent models, it will be included the natural logarithmic transformation of variable RES_TOT in order to have an elasticity coefficient and also because the effect of residents on crime can be assumed to be less than proportional. The age span structure is included in the model using the ratio of residents in age span 0-18 (RES_0.18) and older than 65 (RES_65) over the total number of residents per street. Using ratios instead of absolute numbers of residents lets us avoid collinearity between demographic variables. Moreover, in order to account for the possibility of imported social disorganization (i.e. the amount of social disorganization that might be intrinsic to foreign communities as a byproduct of the social disorganization they had to face in their home countries and that they might have "brought" with them when migrating) we introduced a count variable of foreign nationals by the level of Human Development Index (HDI) of their country of origin. This index, published by the United Nations Development Programme (UNDP 2011), is a composite statistic mediating life expectancy, education, and income indices to rank countries into four tiers (1, for the highest level and 4 for the lowest one) of human development. For each street we computed the number of residents for these four levels of HDI in order to detect a possible dependence of crime from the lowest levels (3 and 4) of this index (variable HDI_LOW). In order to avoid the collinearity problem cited ahead (as the absolute number of foreign nationals is highly correlated with the total number of residents and its decomposition per age spans), we introduced another nationality related (R_FOREIGN) defined as the ratio of total foreign nationals out of the total residents in each street. Finally, the three economic variables we used refer to the number of shops per street (SHOPS), the ratio between the number of shops selling alcohol in each street and the overall length in kilometers of that road (ALCOHOL_SHOPS) and one variable which identifies the presence of medium or large department stores (COMM_VOCATION). The rationale of this variable is the assumption that the attractiveness of a shop is mainly due to the merchandize therein sold and the overall surface of the shop.

Table 3 contains a brief description of the variables considered and the usual descriptive statistics. Whenever a variable has been standardized in order to have more convenient model coefficients, this is indicated with a (STD) indication in the variable description.

Models adopted

Count models are common in criminological research: some authors use Poisson models (Paternoster and Brame 1997; Sampson and Laub 1997; Osgood 2000; Berk *et al*. 2008; Famoye

Table 3 Main descriptive statistics for the independent variables measured at street level.

Variable coding	Variable description	Mean	SD	Min	Max
RES_TOT	Total number of residents	519.08	612.52	3.00	3,192.00
RES_0.18	Ratio of residents in age span: 0-18	0.14	0.05	0.00	0.37
RES_65	Ratio of residents older than 65	0.26	0.08	0.00	0.56
R_FOREIGN	Ratio of foreign national to total	0.10	0.07	0.00	0.40
HDI_LOW	Number of residents born in countries with low HDI level	38.45	57.02	0.00	302.00
SHOPS	Number of shops	10.19	23.58	0.00	133.00
ALCOHOL_SHOPS	Number of shops selling alcohol per kilometer	1.52	3.64	0.00	24.00
COMM_VOCATION	Ability of the shops to attracts customers from other areas	1.95	3.95	0.00	17.13
STREET_LENGTH	Length in kilometers	0.43	0.50	0.02	3.03
CHOICE	Configurational variable of space (STD)	0.00	1.00	-0.40	6.14
INTEGRATION	Configurational variable of space (STD)	0.00	1.00	-5.16	1.25
PERMEABILITY	Configurational variable of space (STD)	0.00	1.00	-0.96	4.07

and Singh 2006; Maltz 1994) whereas others prefer to use the negative Binomial Model as data are overdispersed (Osgood 2000; Paternoster and Brame 1997; Sampson and Laub 1997). In practice, the Negative Binomial Model is derived from the Poisson Gamma mixture model and it is used to model count data when mean and variance cannot be considered equal (Hilbe 2007). Finally, other authors (Famoye and Singh 2006; Miaou 1994) use zero inflated models (Lambert 1992) to face the problem of data containing an excessive number of zero observations which arise when we fail to observe or when we are unable to observe an event. This distinction refers to the difference between the structural zeros and the sampling zeros (Washington *et al*. 2003).

For each of three typologies of crimes analyzed we estimated Poisson and Negative Binomial models both in the traditional and zero inflated way. All the models resulted to be almost identical in goodness of fit, sign and significativity of coefficients and the Vuong tests for the inflation constant in Poisson Models resulted to be weakly or non significant at all. For these reasons we decided to discuss here the Poisson regression model which is the most commonly used for count data, as the benefits of more complex models are not justified by a substantial improvement of model fittings. Anyhow we do not exclude that the other models could not be fruitfully used in different situations, for example for shorter time spans, during which a higher abundance of zeros should be observed, or larger and more heterogeneous areas, where the overdispersion of data may be observed with higher intensity.

In a Poisson regression model we have n observations y_1, y_2, …, y_n (e.g. the number of crimes of each of the n streets in the study area) which can be treated as realizations of independent Poisson variables with Y_i ~ Poisson(λ_i), where λ_i is a parameter specific for the i-th street that represents the expected value and the variance of the number of events for a given time interval, and that we expect to depend on a vector $\mathbf{x}_i$ of p explanatory variables. Being Y_i count data, i.e. non negative integer values, the dependence of λ_i from the p explicative values is expressed through a log-linear regression model:

$$log\lambda_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_p x_{ip} \qquad (5)$$

where β_0 is the constant term and $\beta_1, \ldots, \beta_p$ are the model coefficients. Therefore, the probability of street n_i to observe y_i crimes is given by

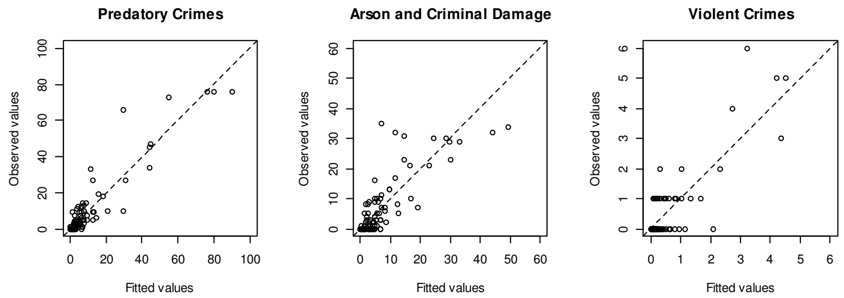
$$P(y_i) = \frac{exp(-\lambda_i)\lambda_i^{y_i}}{y_i!} \quad (6)$$

in this framework model (5) is a generalized linear model (GLM) with Poisson error and log link function. It is easy to derive the maximum likelihood estimators for the vector $\boldsymbol{\beta}$ of the $p + 1$ model coefficients and the tests for the goodness of fit and significativity of coefficients used in the following (see, among the others, McCullagh and Nelder, 1989).

Results and discussion

We present the estimated models sequentially starting from predatory crime (Table 4), moving to arson and criminal damage (Table 6) and concluding with violent crime (Table 7). Each crime category is modeled using two Poisson Models: a Poisson model including all the regressors specified in Table 3 (and therefore named "Full Poisson Model") and a Poisson Model including all the regressors specified in Table 3 except for the ASA variables ("Reduced Poisson Model"). The goodness of fit of each model is evaluated using different measures: Likelihood Ratio test, Loglikelihood, Deviance, Akaike Information Criterion (AIC) and a pseudo-R^2 measure. The first two measures sustain the significativity of the estimated models (p-values < 0.01 for all the models). The deviance difference between the full and the reduced models quantify the explicatory role of the ASA variables (see Tables 4, 6 and 7): 108.78 (p-value < 0.01) for the model of predatory crime, 70.62 (p-value < 0.01) for the model of arson and criminal damage and 3.77 (p-value $= 0.29$) for the model of violent crime. The role of the ASA variables in accordance to the main criminological theories will be largely discussed in the following but, as preliminary remark, we note that their role is strongly significant for the first two categories of crime (for which we note also a significant reduction of the AIC) but not significant for the last one (for which the AIC variation is irrelevant). Moreover, in order to have a common mean of comparison among the models we also give, for each model of the three crime categories, a pseudo-R^2 measured as the squared correlation coefficient between the observed and the fitted values. These coefficients for the three Full Poisson Models that we decided to use as reference models to discuss, result to be, respectively (see Tables 4, 6 and 7), 0.86 for predatory crime (Table 4), 0.73 for arson and criminal damage (Table 6) and 0.71 for violent crime (Table 7), denoting an overall good model fit to real data. As it will be discussed later, the lack of fit for some cases (points far from the dashed bisector line in Figure 3) is due to elements that we decided not to include in the models to avoid any form of overparameterization. There are, for example, some streets whose observed number of arson and criminal damage events are anomalously high if compared to the theoretical ones computed using the model specified in Table 6. This is due to the presence of a soccer stadium in the study area which attracts up to 35,000 supporters who, for their careless behavior before or after the sportive event or even as a consequence of clashes between opposing supporters, generate a number of damages to the vehicles parked in the surroundings of the stadium that is far higher of what it is expected to be on the basis of the pure characteristics of those places. Introducing a dummy variable to include this effect would imply a number of choices that we decided to avoid (for instance, a definition of closeness to this soccer stadium for a street) seeking for a more general model. On the contrary, the presence of a relevant regression residual is important as it is an information that may be used by policy makers: a street that has a number of observed events far bigger than the number of expected ones, points out that there are elements of that specific place which are not included in the model, but which have a negative effect on safety. The policy maker should, therefore analyze any situation in which this regression residual is relevant and investigate these specific bad cases for tailored solutions of a specific problems. On the other hand, if a road has a number of observed events that is far lower than what is expected, these roads have crime deterrents that are not included in the model and that should be studied as good cases to be replicated elsewhere in the city, specifically in the bad cases. A couple of cautionary premises have to be presented before commenting the results. First of all, for the purposes of a model, defining safety with a count number as opposed to a crime rate has a great deal of implications which definitely have to be taken into account when commenting the outcomes. Whereas, for example, routine activity theory insists on the fact that more people means more opportunities for crime and, as a consequence, finding a higher count of crimes where people is more numerous confirms the theory, other paradigms, such as that of natural surveillance, state that crime rates are lower when more people is present in a public space, so that a higher count alone does not contradict the theory (as only a higher rate could). However, as an accurate figure of pedestrian presence in public spaces is not available but can only be inferred from proxy variables, we chose to build the model on the count number and not on the rate. Furthermore, the study area is relatively small and has a certain degree of internal homogeneity, so any a-critical generalization of the findings is unadvisable. The models have instead to be compared with the predictions of the main criminological theories. In this way we can validate each theory as a more or less effective explanatory theory for crime in the study area and, at the same time, we can understand why some variables are relevant and some are not, why their regression coefficient is positive or negative and, finally, what kind of complex social processes they arguably show when they are considered as groups as opposed to considering them one at a time.

Figure 3 - Fitted and Observed values for the three full Poisson models (the dashed diagonal line is the perfect model: Fitted values = Observed values).



The model of predatory crime

The model for predatory crime (Table 4) assigns a positive coefficient to many variables suggested by the criminological theory denoting a direct correlation between each of them and predatory occurrences. Those variables come from each of the three thematic spheres that divide the independent variables we chose: the economic, the social and the configurational sphere. In sum, the model identifies more predatory crimes in those spaces that have more residents, in longer roads, in spaces with more shops, with pubs, bars and other businesses dealing with alcohol consumption and in relatively central public spaces. All of these variables have a very strong statistical significance in the model.

The model assigns negative coefficients to three variables: the percentage of residents of age 18 or less and two configurational variables, choice and permeability. In other words, the more very young people is found residing in a space, the more a space is strategically important in the road network and the more it is permeable through intersecting side streets, the less predatory crimes are found.

Four variables were found not statistically significant despite their link with the criminological theory: the percentage of residents aged 65 or more, the percentage of foreign residents, the residents born in low HDI countries and the presence of medium and large department stores.

Table 4 - Poisson model coefficients for Predatory crime models.

	Poisson Regression (Full Model)			Poisson Regression (Reduced Model)		
	Coef.	**SE**	**p-value**	**Coef.**	**SE**	**p-value**
intercept	-0.889	0.525	0.090	-2.385	0.528	0.000
ln(RES_TOT)	0.492	0.095	0.000	0.719	0.077	0.000
RES_0.18	-4.015	1.697	0.018	-6.272	1.736	0.000
RES_65	-1.265	0.904	0.161	0.052	0.823	0.950
R_FOREIGN	1.037	1.165	0.373	4.482	0.981	0.001
HDI_LOW	-0.001	0.001	0.532	-0.003	0.001	0.000
SHOPS	0.009	0.002	0.000	0.011	0.002	0.000
ALCOHOL_SHOPS	55.255	16.210	0.001	53.433	13.830	0.000
COMM_VOCATION	0.006	0.011	0.556	0.049	0.010	0.000
STREET_LENGTH	0.622	0.089	0.000	0.477	0.073	0.000
CHOICE	-0.147	0.025	0.000	-	-	-
INTEGRATION	0.719	0.081	0.000	-	-	-
PERMEABILITY	-0.436	0.139	0.002	-	-	-
LR Chi2 (dof)	1418.16 (12)			1309.38 (9)		
Log likelihood	-268.67			-323.06		
Deviance	290.08			398.86		
AIC	563.35			666.12		
Pseudo-R^2	0.8596			0.7831		

Routine activity theory (Paulsen and Robinson, 2004) suggests that crime occurs at the temporal and spatial convergence of a suitable target, a likely offender and the absence of a capable guardian. The variables included in the model shown in Table 4 which have been included to portray the routine activity theory are: RES_TOT, RES_0.18, SHOPS, ALCOHOL_SHOPS, STREET_LENGTH, CHOICE, INTEGRATION and PERMEABILITY. The number of residents, the length of a street, the amount of space dedicated to shops and the degree of integration centrality are sensible proxy indicators for the number of suitable targets and likely offenders. Not only they all arguably mean larger numbers of persons (targets and offenders) in public spaces, but they also increase the targets of property crimes like shoplifting, burglary, vehicle theft and theft from vehicle where the proper target is not a person but a shop, a house or an apartment, a vehicle. All of them are also a plausible reason for an increase in the number of potential guardians, but none of them is specific enough, with respect to guardians, to mean that their increase is going to affect the number of capable guardians more or comparably with the increase of suitable targets and likely offenders.

The three variables with a negative coefficient require a slightly more elaborate discussion.

The percentage of very young residents is a surprising predictor of safe streets and is apparently in contrast with findings of much literature[2]. Our study area, however, is small enough to

[2] "It is well established that antisocial and criminal activity increases during adolescence, peaks around age 17 (with the peak somewhat earlier for property than for violent crime), and declines as individuals enter adulthood. Evidence for this so-called ''age-crime curve'' has been found across samples that vary in their ethnicity, national origin, and historical era" (Sweeten et al., 2013)

advise once again to avoid generalizations and its social and cultural context is deeply different from that of much criminological research from the USA. With that being said, a case can be possibly made that, in a social environment with, on average, solid family upbringing and parental control, juvenile deviancy is not only residual, but also displaced to places that are not particularly close to the focal point of parental control like a family home itself, not unlike the case of repeated offenders that are known to usually operate at some distance from their residential environment. Additionally, it is reasonable to think that recently-formed families with young children might have a tendency to settle in areas that, at the time of their relocation, are perceived as safer. It is hard, though, to infer from this an actual, effective selection of safer streets because, for that to have statistical relevance, families should have access to detailed information on crime levels, and should be able to decide where to buy a house regardless of many other, very relevant factors. Both hypotheses need testing. The two configurational variables with a negative coefficient, choice and permeability, can reasonably be considered as factors increasing the number of suitable targets, that of the likely offenders and that of the capable guardians, exactly like the third configurational variable integration.

A case could be made as to why, within the framework of routine activity theory, they might mean an increase in the potential presence of capable guardians large enough to offset the increase of targets and offenders but, in absence of additional research, it is possibly better to just analyze the three configurational variables from a different point of view, as discussed in the following.

The model of predatory crime in a configurational theory perspective

While it is possible to identify a fully developed configurational theory of urban spaces and architecture (Hillier,

1996) a configurational theory of crime can only be inferred by analogy from a number of different sources. These sources include the “eyes on the street” paradigm (Jacobs, 1961), as well as the field of urban planning and architecture (Hillier and Sahbaz, 2005; Sahbaz and Hillier, 2007; Hillier and Sahbaz, 2008; Nubani and Wineman, 2005; Fanek, 2011; Monteiro, 2012) that developed a configurational theory for their own discipline and then attempted to extend it in order to describe the way crime disperses throughout an urban environment. The variables of the model for predatory crime relevant for the configuration theory perspective are the ASA measures: CHOICE, INTEGRATION and PERMEABILITY. A premise of this paper is that a configurational approach looks promising as a way to add a spatial dimension to count models, so we feel encouraged to test the relevancy of spatial configuration despite the lack of a wholly developed theory. Our premise looks to be confirmed by the fact that all three configurational variables are identified by the model as strongly significant. All three are intended as centrality measures, even though the way they define centrality is much different and, as a consequence, their correlations (Table 5 gives the correlation matrix for the three variables) are not high and only PERMEABILITY and INTEGRATION have a correlation which is statistically different from zero (p-value <0.01).

Table 5 Correlation matrix of the three configurational variables.

	CHOICE	INTEGRATION
INTEGRATION	0.1786	
PERMEABILITY	-0.0756	0.3598

At the same time, the idea that centrality in itself can be considered as a predictor is challenged by the fact that the three measures consistently receive coefficients with different signs not only in the model for predatory crimes but in all three models. We conclude, then, that it is some set of specific features of centrality, more than centrality itself, to correlate with crime. In order to identify these features, we have to isolate those (extreme) cases where a couple of configurational variables with opposite signs in their regression coefficient appear, one with a value above the average and the other with a value below the average.

In other words, we should look at those spaces with a configuration that maximizes integration and minimizes choice, and to those that maximize integration and minimize permeability, as the model indicates that they have a relatively larger number of predatory crimes and we want, consequently, to understand what does that configuration mean in urban design terms and in criminological terms.

Highly integrated spaces with relatively low levels of choice are in large part located in the more central and orthogonal portion of the network of the study area. They are streets that intersect main roads or streets that run close and parallel to the main roads. They are well integrated to the urban fabric but their pedestrian and, particularly, their vehicular flow is arguably drained by the more important roads close by, so that the remaining flow can be assumed as local or residual.

On the opposite side of the spectrum, relatively segregated spaces with high levels of choice are relatively important roads that connect the central parts of the study area (and the central parts of the city in general) to segregated, remote, high density residential areas with limited points of access. Alternatively, they can even be the main roads of those segregated residential areas, when those areas are structured so that residential streets all converge to a single main street that is also the first section of the route leading back to the city centre. In sum, such spaces are quite important as collectors of traffic from and to those segregated areas even if they usually channel vehicular traffic more than they do with pedestrian flows that are almost exclusively local.

Considering the other couple of configurational variables, highly integrated but scarcely permeable spaces are close to the main network or part of it but have a relatively small number of side streets. Among them, a notable group consists of roads built on the two banks of a river that, consequently, have very few intersecting streets on one side (a couple of bridges). From a configurational point of view, they are well integrated and, consequently, tend to be relatively well populated with pedestrians, but they are easily controllable because they have relatively few accesses.

On the contrary, segregated and permeable spaces are intricate private streets with a *cul de sac* design and with car access restricted by a gate or they are equally intricate small pedestrian pathways. All of them are extremely peripheral and segregated, arguably characterized by little pedestrian movement. Again, they are easily controllable spaces because, while they have high levels of permeability, most of it is internal to various sections of the private space itself, while the connection between the inside and the outside of this segregated system is well controlled.

At present, with the information that is available, the conclusion that a configurational approach to crime can suggest is that, in the study area, integrated, central spaces with a clear hierarchical dependency from main streets (i.e. side streets and backstreets in the city centre) are places at risk, all the more if they, on their part, have a limited number of accesses/exits.

Comparatively safer are streets belonging to the main, radial road system that lead from the city centre to the periphery, in particular when they are at some distance from the city centre, connecting it with segregated residential areas or when they are the spine of the segregated residential area itself. Another configuration that presents a smaller number of predatory crimes is that of marginal, residential private streets or pedestrian pathways with convoluted shapes and a single controlled or controllable connection with the rest of the network.

The model of predatory crime in a situational perspective

The strong statistical significance of the presence of commercial activities in relation with predatory crime is consistent with the idea that commercial activities generate, *per se,* a situation of risk. Commercial activities, which evidently imply the presence of amounts of money and amounts of valuable goods, create occasions for crimes that are specific (because the target is precisely what is being exchanged in the shop, whether it's the money or the goods) and opportunistic because there is an incentive for the offender to look for shops in order to find a good opportunity to commit the crime. It is impossible, at this point, to disentangle the effect of shops as a direct opportunity for crime from the one mediate by the effect of shops on the number of pedestrians (i.e. suitable targets) but results are consistent with both aspects playing a part. Therefore, the relevant variables of the model shown in Table 4 for this perspective are: SHOPS, ALCOHOL_SHOPS and RES_0.18.

The presence of activities devoted to selling alcohol for direct and immediate consumption is identified as another strong risk factor. Alcohol consumption is a typical risk factor in the situational perspective, even if personal crimes are usually considered more related to it than predatory crimes. Bars and pubs, however, are not only a factor for episodes of drunkenness but can also be meeting places where offenders meet or where offenders identify their targets.

The presence of youth is generally found as a good predictor of crime in general and, in particular, of some specific forms of crime event of a predatory nature. The negative coefficient of this variable apparently refutes this, at least in relation with our study area, where streets with more young residents are relatively safer.

We have already suggested that resident youths are not the same as youths present in the public space and it is conceivable (even though it has to be tested) that potential predatory crimes committed by persons aged 18 or less are preferably committed at some distance from home, but as far as the data at our disposal can tell, no sign of a situational risk factor involving youth was found.

More perspectives, including social disorganization, crime prevention through environmental design, urban density

More perspectives on the determinants of crime can be discussed in the light of our model. Social disorganization is a complex theory and more, specific economic and social variables should be available in order to have a better understanding of its relevance in the study area. However, the percentage of foreign residents and the residents from countries with low HDI are not statistically significant despite being possible predictors of social disorganization just like very high percentages of persons aged 65 or more (which is not significant as well). This is by far too little to exclude the importance of social disorganization as a factor for crime in the City of Genoa, but enough to suppose that, within a small study area with a largely homogeneous population, the small differences in social variables do not correlate much with changes in the number of predatory crimes.

The role of guardians, targets and offenders has been extensively discussed in the section dedicated to routine activity theory; crime prevention trough environmental design and the "eyes on the street" approach operate largely on the same elements. However, the link between scarce permeability and high levels of predatory crimes seems to refute the idea that defensible space automatically reduces crime opportunities. In fact, in our study area the opposite looks to be true: the more a street has limited accesses and, consequently, is controllable, the more it appears to be a good location for a predatory crime, possibly because the offender can easily keep the situation under control and stay alert for the arrival of “capable guardians”. Truth be told, we found a number of residential enclaves to be quite safe compared to the dense and integrated street network close to the city centre, but what really stood out in those enclaves, other than their relative peripherality was their intricate design with multiple sections crossing each other and making their inner design not very much “defensible”.

Finally, urban density is a factor that created much speculation and opposing views as to its role in generating or discouraging urban crime. We didn’t test urban density as a separate variable in order to be able to include its components (number of residents and street length) in the system, but the fact that both variables are significant and their coefficients have the same sign suggests that the relationship between density and property crimes is not particularly simple and linear.

The model for arson and criminal damage

The model for arson and criminal damage (Table 6) contains a number of subtle differences from that of predatory crime. Among the variables with positive regression coefficients, the number of residents, the length of the street and integration are still statistically significant, but the model now adds as significant also the percentage of foreign residents and the presence of medium and large department stores, while the number of shops and the commerce of alcoholic beverages are dropped as non-significant. Meanwhile, the variables with a negative regression coefficient are exactly the same as in the predatory model.

Arson and criminal damage, aggregated in the same statistic, are a little less defined and recognizable criminological category than predatory crime or violent crime. They synthesize simple vandalism, political vandalism, conflict in neighborly relations among individuals or groups and even acts that might be in connection with organized crime.

Table 6 - Poisson model coefficients for arson and criminal damage.

	Poisson Regression (Full Model)			Poisson Regression (Reduced Model)		
	Coef.	**SE**	**p-value**	**Coef.**	**SE**	**p-value**
intercept	0.105	0.541	0.846	-1.485	0.521	0.004
ln(RES_TOT)	0.383	0.106	0.000	0.734	0.088	0.000
RES_0.18	-10.471	1.827	0.000	-11.548	1.804	0.000
RES_65	-0.056	0.896	0.950	-0.418	0.819	0.610
R_FOREIGN	2.502	1.135	0.027	3.564	0.995	0.000
HDI_LOW	0.001	0.001	0.707	-0.001	0.001	0.317
SHOPS	0.004	0.002	0.145	-0.001	0.002	0.834
ALCOHOL_SHOPS	-11.159	23.820	0.639	-20.036	20.528	0.329
COMM_VOCATION	0.026	0.013	0.041	0.058	0.012	0.000
STREET_LENGTH	0.693	0.081	0.000	0.540	0.070	0.000
CHOICE	-0.193	0.032	0.000	-	-	-
INTEGRATION	0.418	0.077	0.000	-	-	-
PERMEABILITY	-0.716	0.157	0.000	-	-	-
LR Chi2 (dof)	805.09 (12)			734.48 (9)		
Log likelihood	-293.58			-328.89		
Deviance	365.29			435.91		
AIC	613.16			677.77		
Pseudo-R^2	0.7255			0.6114		

Unsurprisingly, there is no criminological theory encompassing these phenomena altogether. However, some variables like residents, street length and integration on the positive side and permeability, choice and percentage of residents aged 18 or less are likely to have a similar role here to the one they have with predatory crime. The number of residents, integration and street length roughly suggest the number of suitable targets (directly or via their owners) and the number of motivated offenders. Permeability and choice arguably increase the risk of capable guardians appearing on the crime scene at an inconvenient time for the offender.

The fact that the percentage of residents aged 18 or less is negatively associated with arson and criminal damage can still be interpreted as we did with predatory crime, but again we have to notice that this result is unexpected and contradicts findings of much criminological research.

Even the moderating effect that proximity to parental control can have, can only explain this result to a degree, since arson and criminal damage is a crime category that has a tendency to have a higher frequency of episodes in the late evening and at night, when parental control might not be as effective. This variable and its meaning will have to be tested in other areas of the city to draw better conclusions.

The percentage of foreign residents shows considerable statistical significance and seems to suggest that more foreign residents predict more arsons and criminal damages. The reason for this is not entirely clear and, while we could interpret this as a sign of strained relationships between national groups or between newcomers and locals and as an indication of social disorganization, it is a bit surprising that the variable concerning residents born in low HDI countries does not show the same signs.

While most other variables have a very stable role (significance and sign) in the models regardless of which kind of model is used, the percentage of foreign residents is less stable and so the interpretation of it requires more data.

The presence of medium and large department stores is statistically significant, even if not as much as the rest of the variables. It is an expected finding, since large department stores and malls have frequently been found to be associated with soft crimes and vandalism and to an increased sense of anonymity and lack of responsibility for the maintenance of things and places

(Lagrange 1999; Brantingham et al. 1990). Large parking lots like those of department stores are also frequently found as hot spots for petty crimes.

The study area contains only medium size department stores with a mostly local clientele, even if they still aggregate larger pedestrian and traffic flows, so we expect that in areas of the city with very large commercial venues, department stores and malls this variable might be much more significant.

A few words on the variables that were significant for predatory crime but not here. Shops can theoretically be a target for arson and criminal damage, but the fact that their presence is not statistically significant for the model means that the main targets for these crimes are different (parked cars, street furniture and, to a lesser degree, facades of the buildings apparently are the favorite target). Alcohol as well can be at times a trigger for criminal events like arson and criminal damage but here we have hints that drunkenness, at least in the study area, doesn't seem to be the main driver for criminal acts committed near bars and pubs, at least if we consider vandalism.

One last additional remark has to be made with respect to a very evident landmark of the study area and its impact on the statistics on arson and criminal damage: the stadium. The main stadium of the city, with a capacity of around 35,000 is located in the northern part of the study area and it hosts soccer games of the two local teams at least once a week between late August and May. The site is located approximately at the same distance from the toll station of the highway system and the railway station. In the surrounding area, police forces usually establish pre-filtering points to verify admission tickets and to prevent the introduction of dangerous objects. Pre-filtering points usually become a place of meeting for attendants of the game and can become delicate spots in terms of public order. Some of the urban spaces for which the model prediction is worse and the predicted crimes are underestimated are precisely those where pre-filtering happens.

While stadiums are known to have effects on urban safety in the entire surrounding area (Kurland et al., 2013) it is reasonable that at least the severest effects of it have a slight perturbative effects of the goodness of fit of the model.

The model for violent crimes

Violent crimes are comparatively much less frequent than the other two categories of crimes, with 46 recorded events compared to 897 predatory crimes and 700 arsons and criminal damages. A model built on around fifty events for a study area of 83 urban spaces (Table 7) requires additional caution, and better models for violent crime should probably be built on larger study areas or on longer time frames.

With that being said, the model looks quite consistent with the international mainstream theories if we look at the significant variables and at the signs of their coefficients. The number of residents is statistically significant even if not as much as in the other crime categories, and again it is positively associated with the number of crimes, suggesting that routine activity theory is correct in stating that the number of suitable victims and that of likely offenders is decisive at least to determine the count of crime events in a place. Street length has a similar meaning and ultimately constitutes the leading indicator in the thematic sphere concerning the urban form, but its meaning is influenced as well by the fact that we have tested our models around crime events and not around crime rates.

A finer detailed analysis on individual roads is not possible here, but it is worth noticing that we know of one example of a road which despite being the longest and the one with most residents in the area has no violent crimes, whereas virtually every other long road in the area has three to six.

Table 7 - Poisson model coefficients for violent crimes.

	Poisson Regression (Full Model)			Poisson Regression (Reduced Model)		
	Coef.	**SE**	**p-value**	**Coef.**	**SE**	**p-value**
intercept	-7.493	2.987	0.012	-8.646	2.968	0.004
ln(RES_TOT)	0.905	0.409	0.027	1.061	0.350	0.002
RES_0.18	5.182	8.873	0.559	3.443	9.107	0.705
RES_65	-1.983	4.468	0.657	-1.461	4.078	0.720
R_FOREIGN	1.408	5.812	0.809	5.752	5.071	0.257
HDI_LOW	-0.003	0.005	0.579	-0.005	0.004	0.268
SHOPS	0.006	0.008	0.454	0.006	0.007	0.407
ALCOHOL_SHOPS	162.211	66.435	0.015	177.296	57.814	0.002
COMM_VOCATION	-0.045	0.056	0.422	-0.017	0.051	0.740
STREET_LENGTH	0.879	0.315	0.005	0.742	0.277	0.007
CHOICE	-0.146	0.109	0.181	-	-	-
INTEGRATION	0.469	0.339	0.166	-	-	-
PERMEABILITY	-0.001	0.525	0.999	-	-	-
LR Chi2 (dof)	80.20 (12)			76.44 (9)		
Log likelihood	-56.251			-58.132		
Deviance	53.78			57.55		
AIC	138.50			136.26		
Pseudo-R^2	0.7124			0.6370		

As a matter of fact, either the lack of violent crimes is an aberration or, more probably, our study area is too small and the sensitivity of our model not enough to identify what makes that road different from the others.

Alcohol commerce is found significant and positively associated with violent crime and, again, this was expected. The link between alcohol and crime in the study area, however, does not appear to be trivial in its meaning and in the way it works. While, in absence of an answer, we can still consider drunkenness as a possible reason for violent crime in the area, we should also consider the possibility that bars and pubs might be a place that aggregate relatively sober likely offenders and that their predatory or violent acts might not be driven mainly by alcohol intoxication.

Conclusions

In the study area, criminal events of any kind seem to be primarily a product of opportunity and routine activity theory looks like the most explanatory among a number of theories. In this relatively homogenous area, where mixed use of space is the norm but residential density is nonetheless quite high thanks to the architectural typologies that are most common, longer streets, with more residents and more residential units attract more crimes of each of the three typologies analyzed here. Shops, bars and pubs are other good predictors, most probably for the reason that they do not only indicate greater opportunities but also because they attract specific forms of crime. However, they have a less generalized effect, meaning that both shops and bars appear neutral to arson and criminal damage. As for the configuration of the street network, it seems to identify a specific type of spaces, mostly side streets and backstreets of main roads (even when they have some importance of their own), particularly when they have a limited number of direct connections with other roads. Those spaces apparently suffer from a greater risk of predatory crimes, arson and criminal damage. Finally, although social variables concerning the composition of the population per nationality or age have shown occasional significance and their interpretation is not always evident, the overall sphere of social variables that we used, has the remarkable advantage of consisting of simple, rigorous information that is easy to collect through official data and, in literature, it has a history of being profitably used. Personal income was found relevant with several other socio-economic indicators for a measure of deprivation which in turn has been demonstrated to be correlated with crime (Land *et al*. 1990; Messner and Rosenfeld 1999; Sampson, Morenoff and Gannon-Rowley 2002, Mears and Bhati 2006). However, the income of residents is, for the time being, not available.

From the analytical point of view, in this paper we decided to follow the mainstream approach of using count models for crime analysis while introducing a number of innovations. The introduction of the configurational variables in these traditional count models used to describe criminal occurrences, gave interesting results under two main points of view. First of all, the goodness of fit of the models is significantly improved by the use of these variables as a complement to the traditional socio-economic regressors. This is a remarkable outcome as we are making use of a quantitative description of the urban layout that is objective and based on measures that are easily repeatable in any other urban context. Secondly, the sign and significativity of the coefficients of the models are consistent with the main criminological theories and stable throughout all the estimated models. Additionally, we proposed a model built around a relatively large number of variables covering a vast thematic field, so that the model can be considered multi-theoretical.

The final remarks that we propose for future improvements of this work relate both the set of regressors used in the models and the models specification. In the light of these mixed results with socio-economic variables, the social drivers of crime (like social disorganization, strain, violence subcultures, local conflicts and unsupervised youth), if relevant to the social context that we analyzed, probably require more sophisticated variables and larger and more varied study areas to emerge. This analysis is focused, in fact, on a single district of a city and it would be interesting to compare these results with those of other districts or those of other cities with different spatial and socio-economic features, in order to validate the effectiveness of the variables in different contexts of application. At the meantime, not every theoretically relevant explicative variable could be included in the model for the aforesaid privacy reasons. Whereas, in larger scale studies, this gap of information may hinder the predictive capabilities of the statistical model, in this case the study area is quite limited and we do not expect to find, anyway, relevant heterogeneity in income indicators in the streets included in the area. Therefore, income data would probably bring little improvement to the models. From a technical point of view, in order to remain consistent with the widespread use of count models in quantitative criminological literature, we assumed all the explicative variables to be spatially uncorrelated phenomena even if our variables are geo-referenced at street level, i.e. are lattice data (e.g. Cressie 1993). The traditional models used for lattice data (Spatial Autoregressive or Conditional Autoregressive models) are not applicable for count variables, as their conditions of applicability are not compatible with the nature of criminal data. However, in epidemiology, as well as in other contexts, some authors developed Bayesian methods (e.g. Besag, et al. 1991) that overcome these limitations separating spatial effects from heterogeneity. It has been proved (Berry et a. 1992; Cohen et al. 1998; Law and Haining 2004; Zhu et al. 2006) that hierarchical Bayesian models can be profitably applied to the spatial analysis of many social and health problems and to the analysis of crime data as well. In this perspective, it will make sense to evaluate the role of the autocorrelation term, specified through adjacencies matrix of streets. If this spatial autocorrelation component is statistically significant as it is implicitly included in the three ASA variables, hierarchical Bayesian models could result as an improvement over count models, otherwise the widely used traditional count models may be a good solution also in future works.

Another issue that should receive more attention in the future is the specification of lattice models for risk rates in place of those for occurrences. Again, epidemiological literature can be an inspiration, since morbidity rates present problems that, while contextually different, are also structurally similar to those concerning crime counts and crime rates. Using rates instead of counts, however, presents a few challenges. Rates are a probability statement and they establish a relationship between events that happen to a population and that population (Boggs 1965). In all evidence, in order to formulate accurate rates, the population has to be identified precisely which is not always easy: a population can be elusive, may vary over time in the 24 hours, from day to day during the week or in different periods over a year. Some crimes which have places or property as a target, like burglaries, vehicle thefts or thefts from cars refer to populations (residential units, parked vehicles) that are not always available. Another notable issue comes from the fact that rates assume the magnitude of opportunities for crime as a trivial, self-evident correlate of crime itself. This idea has some support in literature, but others argue that using opportunity as a denominator in crime rates and, consequently, "controlling" for it, subtracts structural variables from the model that are neither spurious nor trivial and that a model of urban crime should analyze (Chamlin and Cochran, 2004). Finally, rates have a specific meaning which is not necessarily better or worse in explaining crime, but is certainly different and, while the reasons behind a distribution of crime rates across a city can be of interest to certain public agencies, others may have more interest in counts than they have in rates.

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