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Urban Design, Space Syntax and Crime

An evidence-based approach to evaluate urban crime geographical displacement and surveillance efficiency.

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ABSTRACT

Spatial configuration analysis plays an important role in understanding the materials and intangible factors within built environments. *Space Syntax* is an important instrument in that aspect, as the decomposition of space in *Isovists*, *Road-Centre Lines,* or *Visibility Graphs* emulate tendencies of human natural movement in urban contexts. From the early '90s, Space Syntax methods have been applied to crime science, to unveil connections between urban design, citizen behaviour, and where crime occurrences happen; in fact, the urban space features are assumed in the literature as key factors to crime prevention. Several studies investigated relations between crime distribution and street-networks' spatial configuration identifying important correlations between movement, natural surveillance, and crime occurrences. Hence, the possibility to investigate the relationship between the crime distribution and the visual fields (VGA) in the urban scenario from the perspective of natural control emerges and represents an intriguing aspect, yet to be explored and integrated with other analyses. With this in consideration, this paper contributes to these discussions, as it evaluates the geographic distribution of crime occurrences regarding drug dealing and car break-ins offences in the historic centre of Pisa (Italy) and their possible correlation with street networks' configurational properties. Starting from the *Isovist* concept, the spatial features of visual control and controllability measures (VGA) are investigated, as they represent useful tools to interpret the rational offender logic in deciding the suitable locations and opportunities to commit a crime and, as a consequence, to indicate a direction to lead crime prevention interventions. Further in-depth studies are finally proposed.

KEYWORDS

Crime distribution; Surveillance; Space Syntax; Visibility Graph Analysis; Control

1 INTRODUCTION

Urban security has turned, nowadays, into a major concern in the public debate, both scientifically and from a social and political perspective. The inner complexity of the matter is due to the complexity of the two highly interconnected systems involved, city and crime, with the latter being the focus of several major studies since the ’60s (Cozens and Love 2015). At that time, following numerous urban and social studies (Shaw et al. 1929, Shaw and McKay 1942), the matter started to lean towards an integrated urban-social approach as a result of important research findings produced by Wood (1961), Jacobs (1961), Angel (1968), Jeffery (1971) and Newman (1972) among others. Therefore, in the following few years, the social approach and the environmental approach to security emerged (Wortley and Townsley 2017) and then continued to offer interesting research insights, which may prove to be integrative to the traditional criminal justice system. In particular, these approaches aim at preventing criminal events and contextually reducing the fear of crime, with the latter being currently identified as a more widespread issue than the crime itself (Hale 1996, Bannister and Fyfe 2001, Fasolino, Coppola and Grimaldi 2018). In fact, Maslow (1943) already highlighted in his hierarchy of basic human needs the importance of security, a factor that ought to be granted by the city, which is defined as a place of social interactions (Ceccato 2012). However, these needs are not always met. Rather, the conditions in which increasingly urbanised and populated cities are set, make this objective highly unlikely to achieve (Colquhoun 2004) as cities are now considered crime generators, opposing to their original qualification of the ‘source of security’. It is indeed increasingly believed that the generated social vulnerability and insecurity tend to undermine citizens’ well-being (Bibri 2018, Van Soomeren 2013). Therefore, it has become fundamental to detect which dynamics govern the city system, how crime evolves and occurs, and which factors feed the fear of crime. Regarding this, according to the environmental approach, it is essential to develop methodologies that may allow analysing the urban distribution of crime to be linked to the crime theories developed within the scope of environmental criminology. In this way, it will be possible to assess potential links with urban design and create support tools that may help the decision-making process to improve urban security.

Space Syntax plays a crucial role in this sense. Links between crime distribution and urban configuration have indeed been proven through configurational studies (i.e: Shu 1999; Hillier and Shu 2000, Hillier and Sahbaz 2005, Nubani and Wineman 2005, Van Nes and Lopez 2010, Summers and Johnson 2017, Van Nes 2017). Generally, those Space Syntax urban studies have been conducted as axial analysis, searching for urban design, movement, and crime correlation. However, there are some inconsistencies caused by dissimilar methodological approaches (Summers Johnson 2017), which bode a methodological reorganisation aiming at solving these previous studies’ controversies and assessing the actual connection between integration, choice, and connectivity measures and crime distribution. Moreover, Visibility Graph Analysis (VGA) applied to an urban scenario is believed to be an excellent research field (Turner 2004, Koutsolampros et.al 2019), yet still uncharted in its correspondence with the crime. By adopting a multi-analysis integrated study, it is indeed possible to retrieve useful information about crime distribution logic and potential surveillance actions to be taken, that can be incorporated into the Axial-based analysis. This paper shows preliminary results of a research study based on the city of Pisa (Italy), which introduces an integrated approach of axial analysis and visibility graph analysis to comprehend crime distribution logic with particular attention to the aspect of surveillance. The paper's structure is as follows: first, the theoretical framework is presented, both from a criminological and methodological viewpoint, namely the crime theories and the Space Syntax measures used in the analysis, especially those related to the VGA. Secondly, the research data are investigated, especially focusing on their consistency and the rationale for selection. Thereafter, the core discussion is presented: a general overview of Pisa's urban configuration at the municipal scale is presented through a qualitative discussion of its road-network, modelled using *Angular Analysis* (Turner 2001a), then, an urban-based analysis of the historic district, is produced. In this case, an *Axial Analysis* is performed as it most accurately describes the natural movement of pedestrians in the city centre (Hillier 2007) and can be combined with the *Visibility Graph Analysis* (VGA). Contextually, this analysis examines the local visual control and visual controllability measures as tools to understand the crime distribution logic and propose future developments potentially based on CCTV images or light spots in the city centre, as both these tools are highly connected to visual fields. In this sense, a comprehensive VGA-based study could provide effective insights on the offenders' *modus operandi* and citizens' fear of crime, in accordance with the rational choice perspective (Clarke and Cornish 1985, Cornish and Clarke 2016). Conclusions and suggestions on possible future research developments are eventually proposed.

2 THEORIES FOR CRIME PREVENTION AND SPACE SYNTAX

2.1 Crime prevention theory

The environmental approach to security traces its remote origins in the studies developed by the Ecology School of Chicago in the '30s (Bolici and Gambaro 2020, Wortley and Townsley 2017) that first addressed the issue of crime in terms of social behaviour and neighbourhood organisation (Cozens Love 2015). Subsequently, at the turn of the '50s and '60s, in America many scholars open the scientific debate on the organisation of the city (i.e: Lynch 1954, Hall 1959, Lynch 1960, Sommer 1969), investigating the criminal phenomenon and the link with urban design and society (Wood 1961, Jacobs 1961, Angel 1968).

However, the environmental approach to security has fully developed since the '70s, after the significant contributions of the criminologist Jeffery (1971) and the architect Newman (1972). With their works, CPTED (Crime Prevention Through Environmental Design) was born: a theory according to which the environment could have a strong impact on criminal behaviour and the assumption that through urban design and environment modifications crime occurrences could be reduced. The development of the CPTED theory increases the research about possible existing connections between urban configuration and criminal events.

Many studies show that crime is not randomly distributed in terms of space and time (Brantingham and Brantingham 2017, Rosser et.al 2016), and each type of crime follows particular distributions. Therefore, it is essential to understand the logic and patterns that follow the crime occurrences: on the one hand, crime mapping allows to visualize the physical distribution of crimes occurring in the urban environment (Rosser et.al 2016); on the other hand, the crime prevention theories focus on the situations, dynamics, opportunities and distribution of crime analysing the offender just as an element of the crime scene (Wortley 2008).

Crime prevention theories represent a fundamental tool both from the analytical perspective, to understand the logic behind antisocial behaviour, and from the operational perspective, defining specific environmental interventions to prevent crime occurrences (Wortley and Townsley 2017). The environment is here considered in its broadest sense, as originally conceived by Jeffery and in the second and third CPTED development (Saville and Cleveland 1997, Mihinjac and Saville 2019), by including concepts of opportunity, pattern, rational offence, social behaviour, and liveability.

Among the most significant theories there are the rational choice perspective (Clarke and Cornish 1985), the routine activities approach (Cohen and Felson 1979), and the crime pattern theory (Brantingham and Brantingham 1981). Each theory focuses on different aspects of the criminal phenomenon, analysing the environment from a different point of view. Depending on the type of crime or context to be analysed, one theory may therefore be particularly functional rather than another. However, an integrated vision of the various crime prevention theories, considering their "interconnected nature", allows for having a global vision of the possible causes that can interact in generating the conditions for a criminal event. The rational choice perspective shows how the offender acts according to rationality, judging the best situation in which to commit crimes, and rationally assessing risks and possible gains. The routine activity approach highlights instead of the basic conditions for which a crime occurs, namely the simultaneous convergence in space and time of three elements: a motivated offender, a suitable target, and the absence of a guardian (Cohen and Felson 1979, p. 589). The crime pattern theory dwells instead on the existence of cold and hot spots in crime distribution, on the concept of opportunity that can provide the environment for the realisation of a specific crime, and therefore on the interventions that can be made to counteract the 'crime patterns', also clarifying the role of crime generators and attractors (Brantingham and Brantingham 2017). In these theories, surveillance represents a decisive aspect of the environment for crime prevention purposes. In fact, by increasing the level of surveillance in an area - whether formal, therefore referred to the presence of police forces, CCTV, sensor systems, or informal and therefore of the Jacobian matrix, which referred to as the presence of eyes on the street - the crime opportunities reduced (Gibson and Johnson 2016) because of the loss of one of the three contextual conditions that according to Cohen and Felson (1979) must be satisfied for a crime to occur. Additionally, the presence of 'guardians' also affects perceived safety. Leaving aside the borderline case of the 'transparent city' as a means of exerting the dystopian continuous external control (Paone 2019), the presence of 'guards' (which can be Jacobian eyes on the street, Newmanian neighbourhood control, presence of police forces...) can actively intervene reassure the citizens (Jacobs 1961) and disincentives a possible offender in the realisation of crime according to a rational benefit-cost logic (Wortley and Townsley 2017).

In this, the topic of CCTV control in the urban context, combining the preventive effect (disincentive action) with the repressive one, is very topical. The conditions, methods, and timing with which CCTV data can be collected and used are in the middle of the political, social, and juridical debate, especially concerning the integrated and technologically advanced perspectives of smart safe cities (Park Lee 2020). Systems are characterised by undoubted potentialities given by the contextual technological and IT progress, but also by the serious shadows generated by the lack of research highlighting beneficial effects in terms of lowering both crime rates and fear of crime (Laufs, Borrion and Bradford 2020). Therefore, having discussed crime mapping and crime prevention theories as fundamental analysis and interpretive tools for crime detection and prediction, it is necessary to investigate further tools and methodologies capable of relating crime occurrences to urban configuration. For this purpose, *Space Syntax*, especially the VGA, seems to have great potential and still plenty of room for development, as it captures the visual aspects that can be related to the surveillance of spaces.

2.2 Space Syntax theory

Space Syntax is an important instrument for analysing and understanding the material and immaterial aspects of the urban environment (Yamu, Van Nes and Garau 2021), as it can address the urban grid with all its interconnected elements as well as determine the human patterns of movement that influence people decision-making and spatial behaviour (Hillier 2007, Hillier et.al 1993, Hillier 1999, Van Nes 2002). So, the configurational analysis, through axial lines and visual graphs, plays a fundamental role in interpreting human natural movement in the city and in making explicit some aspects dependent on the spatial configuration, otherwise hidden.

Within the environmental approach to security, relationships between crime distribution and Space Syntax measures have been sought (Alford 1996, Shu 1999, Hillier and Sahbaz 2005, Nubani and Wineman 2005, Van Nes and Lopez 2010, Summers and Johnson 2017, Van Nes 2017): specifically, integration, choice, and connectivity measures. Integration represents the topological distance of each segment to all other segments in the network using the shortest path algorithm, thus indicating the probability of a segment being the destination of those travelling through the network. Choice represents the frequency with which each segment is travelled, considering all the shortest paths that connect all possible origin-destination pairs of the network.

It is therefore a measure of through-movement potential. Finally, connectivity is simply the number of segments intersected by each segment (Hillier and Hanson 1984, Hillier 2007), interpreted as a measure of local accessibility. Both Integration and Choice measures were later reworked into their *Angular* (Turner 2001a) and *Normalized Angular* (Hillier et.al 2012) metrics. Despite crime distribution such as street robbery has proven to be correlated with street segments with high integration and choice values by many researchers (Alford 1996, Farooq 2007, Hillier and Sahbaz 2005, Sahbaz and Hillier 2007), there are several conflicting studies on the relationship between accessibility and crime (Cozens 2011, Summers and Johnson 2017). In fact, some researchers argue that high accessibility is associated with a higher frequency of crime occurrences (i.e: Baran et.al 2006, 2007) while other studies argue that more segregated and poorly connected segments are generally subject to higher victimisation (Hillier and Sahbaz 2005, Nubani and Wineman 2005, Van Nes 2017). Summers and Johnson (2017) attribute these inconsistencies to the different adopted methodological and analytical approaches, whereby studies developed differently may also lead to significantly different results. However, the generalisation in terms of relationships between crime occurrences and urban design characteristics is not particularly significant in terms of crime prevention theories, as it does not consider the different conditions that may perhaps favour one crime over another. Moreover, such research cannot be exhausted with a configurational analysis; rather it must be accompanied by interpretative tools and other relevant aspects such as the analysis of the specific urban environment characteristics in terms of social context, activities distribution and land use, and existing dynamics. However, the field of *Visibility Graph Analysis*, applied at the urban scale, is still a rather unexplored application of *Space Syntax* (Koutsolampros 2019). The VGA is often used for architectural scale studies, for example, to evaluate distributive aspects of buildings, but due to its complexity and long processing time-lapses, its application in larger settings remains still hindered. Yet, if properly analysed, VGA can provide useful information even in urban or neighbourhood contexts, and, associated with the *isovist* representation of Axial Analysis, it can be very interesting in the criminological interpretation. The *isovist* is defined as the set of points visible from a given point of the analysed environment (Benedikt 1979). Thus, the analysis of urban space in terms of visual fields can offer remarkable insights when associated with the social and behavioural aspects of people living in those spaces. Jane Jacobs (1961) first discussed the importance of eyes on the street as a deterrent to anti-social behaviour, but later nearly all the researchers in the environmental field have approached the theme of surveillance, control, and the influence of open visual fields on the security and perception of security (Newman 1972, Newman 1996, Wagers, Sousa and Kelling 2017). In particular, the study of some particular VGA measures such as visual controllability and visual control can provide very useful information about the environment from a criminological perspective (Turner 2004), especially from the surveillance standpoint. Both of these measures relate the concept of visibility to that of control (Koutsolampros 2019). Both described by Turner (2001b, 2004), they are quantities considered semi-global as much as they describe spatial properties associated with the immediate visual field space extended by one visual step (Koutsolampros 2019). Visual control is the implementation of the 'Control' measure coined by Hillier and Hanson (1984). It was defined by Turner (2001b, p. 6) as the value obtained by "summing the reciprocals of the neighbourhood sizes adjoining the vertex" and it is expressed by the equation:

$$Visual\ Control = c_i = \sum_{v_j \in V(\Gamma_i)} 1/k_j$$

It is then a measure that highlights the visually dominant areas of space (Turner 2004). In fact, it relates the area directly visible from a cell to the visible area determined by the cells in the visual field of the first cell; therefore, the higher the value of control, the wider the cell's visual field will be compared to its directly visible cells. In particular, if $c < 1$, the space directly visible from the examined cell will be less than the one seen by the other directly visible cells (not being so a good 'controlling point'), and in particular, the cells offering the lowest contribution to the visual control value have to be evaluated as possible best controlling points (highest visual control value). The opposite happens for values of $c > 1$. The example of Bentham's panopticon is emblematic: perfect controlling location of the central point, bad controlling location of the guarded cells (Turner 2004). However, the orthogonal grid scheme used in the military camp (Figure 1) is also an excellent example, as it highlights the functionality of the grid layout in terms of control, considering the visually dominant area determined at the intersection between the axes.

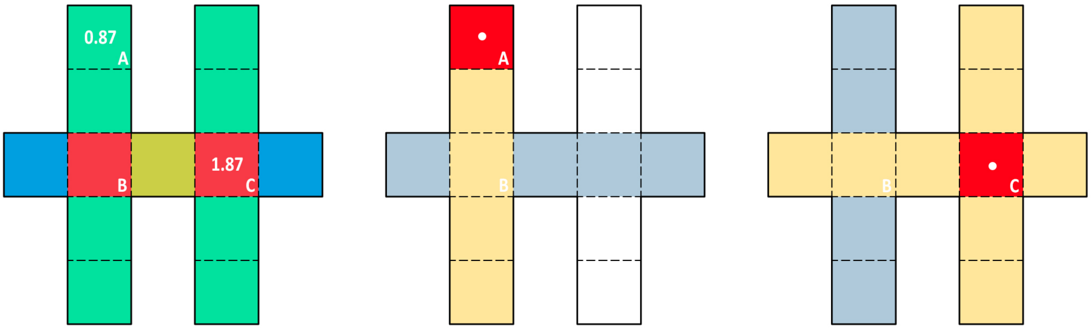

Figure 1. (a) Visual control. (b) Cell A can see 4 cells directly and each of them sees 4 cells except cell B, which sees 8 cells, thus obtaining a controllability value of 3*(1/4) + 1/8 = 0,875 (c) Cell C can see 8 cells directly and each of them sees 4 cells except cell B, which sees 8 cells, thus obtaining a controllability value of 7*(1/4) + 1/8 = 1,875

Visual controllability, introduced and described by Turner (2001b, 2004), is a measure of how controllable a location is. It is expressed as the ratio between immediate visible cells and the sum of all visible cells from immediate neighbour cells (Koutsolampros 2019). It is expressed by the formula:

$$Visual\ Controllability = c'_i = \frac{k_i}{\cup N(v_j) : v_j \in N(v_i)}$$

This metric offers a measure of how much space a cell sees compared to the field of view of the cells that compose its immediate neighbourhood, assuming values close to 0 where there is low controllability and values close to unity where there is high controllability.

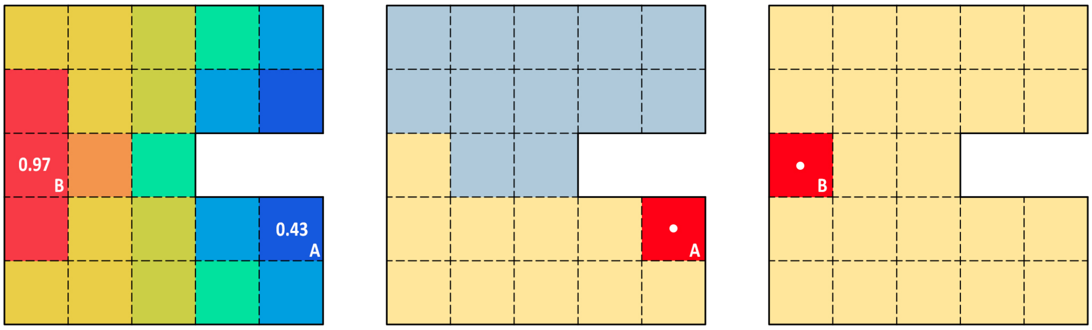

Figure 2. (a) Visual Controllability. (b) Cell A can see 10 cells directly and 13 through its neighbours (including cell A) thus having a controllability of 10/(10 + 13) = 0.43. (c) Cell B can see all 22 cells and so can all the neighbours (but also including cell B) and thus has a controllability of 22/23 = 0.97. Adaptation of Koutsolampros et alii (2019, p.8)

In particular, the elaborations and qualitative analyses presented in this paper analyse these quantities in the urban context, looking for correlations with specific typologies of crime (see next paragraph), as suggested by Turner (2004). The correlations have been searched through a critical reading of the measures of visual control and visual controllability integrated by criminological theories and by an analysis of the city context of Pisa, to evaluate the dynamics and patterns of drug dealing and car break-ins offences.

3 DATASETS

3.1 Geo-referenced crime data

The crime data were provided by the Prefecture of Pisa, being sourced from the SIGR database, property of the Italian Ministry of Interior. The original selection of crimes to be investigated in this study was dictated by their presumed link with the environment, and so the typologies initially considered were the following:

- voluntary homicide;
- theft (art. 624, 624 bis and 625 of the Italian Penal Code);
- robbery (art. 628 of the Italian Penal Code);
- drugs related (articles 73, 74, 75, 79 and 38 of the Italian Penal Code).

However, the legal classification of types of crime is inconsistent from a criminological point of view. This is because under the denomination "theft", for example, various sub-typologies do not respond to the same logic and do not occur under the same conditions, and therefore respond, unless proven otherwise, to a different model of spatial-temporal distribution.

Theft-related	Robbery-related	Drug-related
a. with snatch	a. in apartment	a. production and trafficking
b by stealth	b. in bank	b. dealing
c. in public offices	c. in post offices	c. association for prod. and traffic.
d. in apartment	d. in shops	d. association for dealing
e. in shops	e. to jewelry stores	
f. car break-ins	f. to bank values transporters	
g. of art works or antiquities	g. to postal values transporters	
h. to heavy cargo vehicles	h. in public street	
i. of mopeds	i. to heavy cargo vehicles	
j. of motorcycles		
k. of cars		

Table 1. SIGR classification of theft, robbery, and drugs related offenses

It would therefore be illogical and misleading to seek correlations between different sub-typologies of crime and spatial configuration: for example, referring to the desired conditions searched by an offender, a stealth theft is more likely to occur in a crowded place where contact between strangers does not give particular cause for suspicion. The opposite happens for a premeditated robbery, for which the offender will look for a segregated area. Considering the various SIGR offences subcategories (see table 1), the following specific offences were finally analysed:

- drug dealing;
- car break-ins.

The remaining sub-categories of crime have been temporarily excluded, despite their obvious connection with the concept of surveillance, to be further studied also on a micro-urban scale: theft or robbery in apartments; thefts of mopeds, motorcycles and cars; robberies in banks, post offices, shops, and jewelry stores; robberies on public streets. Voluntary homicide, on the other hand, was excluded due to the insignificant number of events in the selected period (< 3).
Data were requested for the 5-year time period from January 1st, 2015, to December 31st, 2019, thus obtaining a large enough database to perform the established studies. Both consummated and attempted crimes were included, as this does not represent a relevant discriminating factor in terms of crime prevention.

These datasets are spatialized in QGIS 3.16 as different heatmaps, in order to show the spatial distribution of these criminal activities.

3.2 Cartographic Databases

Datasets used for the general configurational analysis of Pisa municipality are obtained from the regional road infrastructure outlined in the *Grafo Iter.net*, an RCL graph dataset constructed and maintained by the Tuscany Region's *Sistema Informativo Territoriale ed Ambientale* - SITA (2016, 2019a). The extraction of this dataset was made in QGIS 3.16 (2020) and then the resulting graph was exported to DepthMapX 0.8 (2018) where we conducted the *angular segmentation* and the *angular analysis,* further normalising the maps according to Normalized Angular Integration (NAIN) and Normalized Angular Choice (NACH) principles (Hillier et al, 2012).

To construct the *Axial Analysis* and the *Visibility Graph Analysis*, we used several Technical Regional Charts – (*Carte Tecniche Regionali* – CTR), also constructed and maintained by the Tuscany Region's *Sistema Informativo Territoriale ed Ambientale* – SITA (2019b). Several CTRs were combined in QGIS 3.16 (2020) to create convex spaces with reference to the Pisa historic centre. Territorial frameworks for the Axial, Angular and Visibility Graph analysis are depicted in Figure 3. Those were then exported in DepthMapX 0.8 (2018) where we generated the *Axial Map* and the *Visual Graph*. First, the convex space grid was set to 2, which is the smallest spacing allowed for the Pisa's historic area to obtain the most detailed visual logic possible. Then, the *Visual Graph* based on this grid was constructed, and the measures of visual control and visual controllability were run. The results were then exported to QGIS (2020), and categorised according to an equal count (quartile), so the 10% of the visual areas within the lowest values of control and controllability were highlighted. The axial map is constructed within the same convex space as the *Visual Graph.* The chosen measures were Integration (HH) and Normalized Choice, both at a global scale, as well as the connectivity. These metrics were also exported to QGIS (2020) and categorized according to an equal count (quartile), to highlight the 10% of the road elements within the lowest values of Integration and Choice.

In GIS, both datasets were spatialised as overlays to the CTR, in order to associate the configurational metrics to the foreground and integrate the geospatial crime datasets.

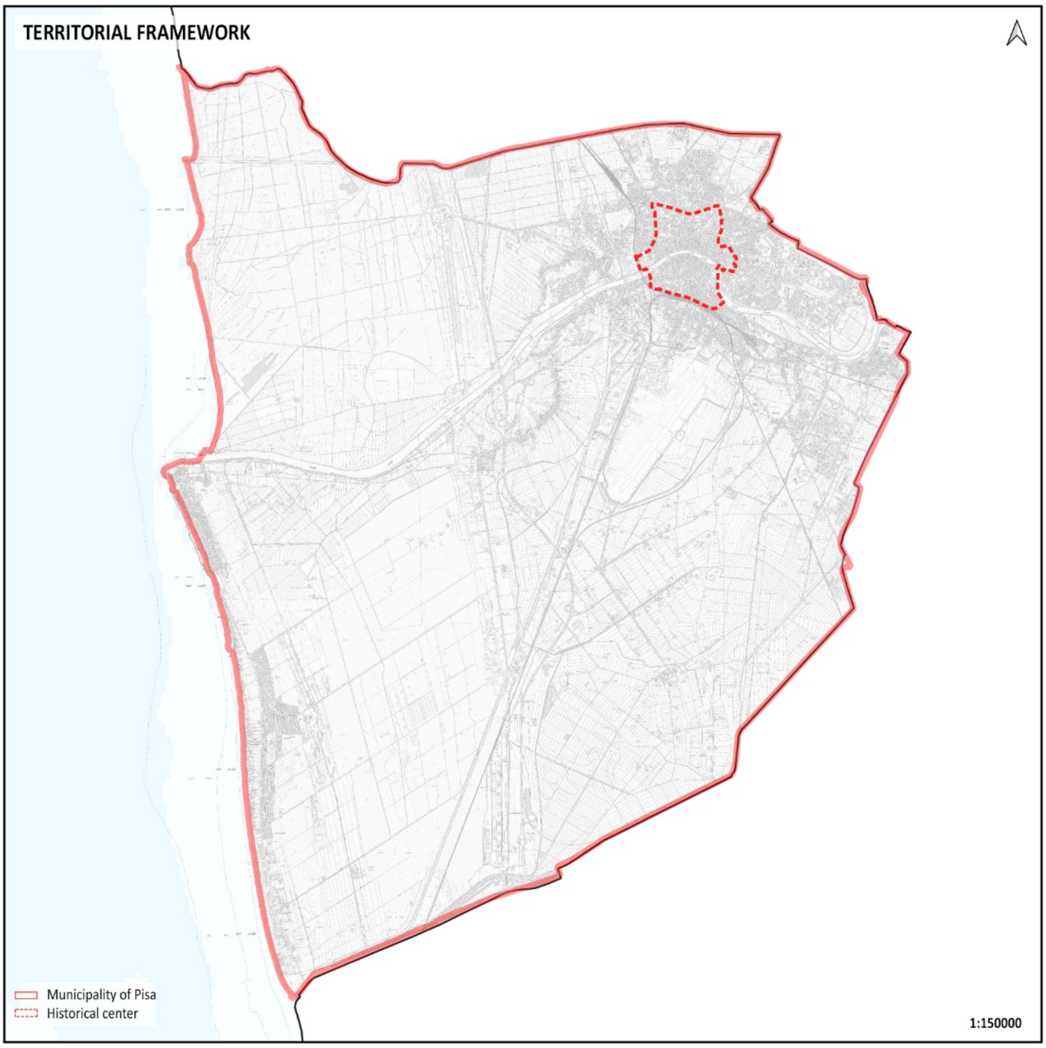

Figure 3. Municipal area and historic city centre of Pisa

3.3 Data discussion

The geo-referenced data related to drug dealing and car break-ins have been acquired with a limitation, namely the impossibility of obtaining geo-referenced data related to crimes, by subcategory, occurring in a number of less than three per single street, for privacy issues. Due to this limitation, it was decided to work on a time period of 5 years, in order to minimise the amount of data lost. Specifically, considering the entire municipality, it turned out that due to this limitation, 22,8% of drug-related crime offences would be excluded. Due to this limitation, that hopefully will soon be resolved, it was also decided to perform a qualitative analysis instead of a quantitative one, managing to bypass the problem by directly extracting from the SIGR the distribution crime maps, avoiding this way any limitation and data loss. So, the heatmap distribution of crimes was obtained and subsequently processed (see next paragraph). Therefore, it was possible to search for relationships with the urban configuration through the analysis of Space Syntax measures, the reading of the environment, and the interpretation from a criminological perspective.

4 RESULTS

The preliminary results of the investigations are here presented: an *RCL Analysis* at the municipal level to show the urban development of Pisa and then a combined *Axial Analysis* and *Visual Graph Analysis* in the city centre to evaluate the crime distribution.

4.1 Municipal network: RCL analysis

An RCL Analysis was carried out on the entire municipal territory to show the area and its network organisation. Figure 4 shows the global Normalized Angular Integration (NAIN) and Normalized Angular Choice (NACH) measures. As seen in Figure 3, the historic centre is decentralised from the municipal area, being located on the northeast border of the municipality.

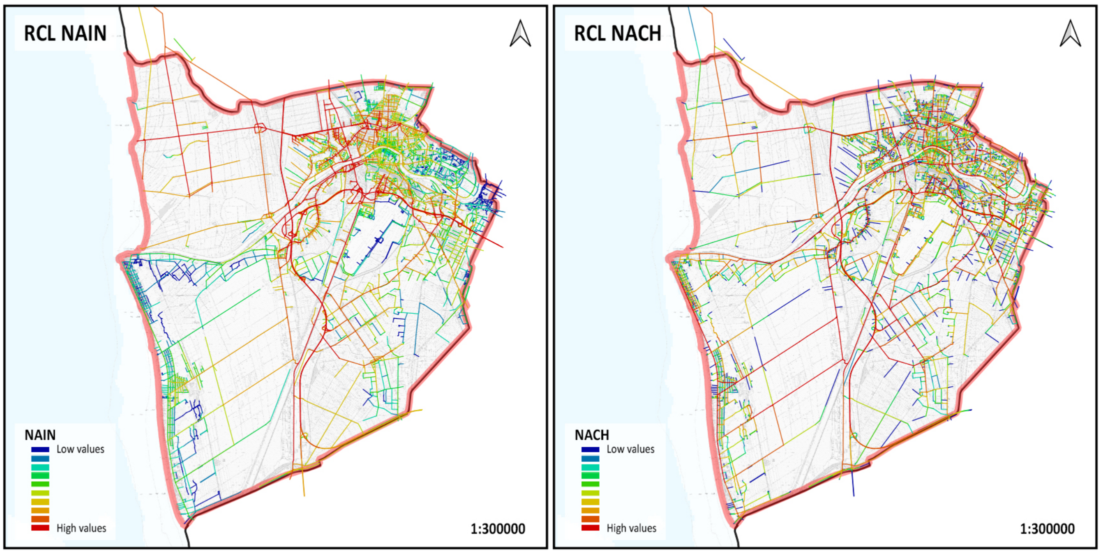

Figure 4. Road Centre Line analysis of Pisa. a) NAIN b) NACH

From a configurational standpoint, the NAIN analysis demonstrates that relative accessibility is structured around a central integrated group of road elements, which represents the interstate road system. This divides the municipality into two minor relatively segregated areas, one to the west, which represents the coastal area *(Marina di Pisa)*; and the other, the modern residential expansion towards the east. At the municipal scale, the historic centre resides in proximity to these modern residential segregated areas, set in-between medium ranges of integration, with several inner areas also having low relative accessibility. The NACH analysis depicts the flow structure, which is concentrated on the interstate highways and the avenues that connect the city to the coastal area and make up Pisa's historic centre outer ring-roads around the walled part of the city.

The inner historic centre, however, is crisscrossed by three main preferential routes, two that run along the *Arno* river (*Lungarni*), and one that connects the residential area to the historic centre, set on the southern bank of the Arno River, where the municipal train station and other important urban equipment are located. The inner parts of the historic centre, especially in the northern margin of the *Arno* river, are made up of rather orthogonal grids mostly devoid of preferential routes' presence, being lower in the flows' hierarchies. These areas have important relations with criminal activity, which will be discussed in the historic centre analysis.

4.2 Crime distribution analysis in the city centre: Axial Analysis and Visibility Graph Analysis

Concerning the analysis developed in the urban centre of Pisa, first, an *axial analysis* was conducted and then a *visibility graph analysis* was performed. The analysed area consists of the portion included inside the ancient city walls extended to the south up to the margin determined by the railway line. As said before, the city is crossed by the *Arno* river, which characterises the urban configuration. It determines the presence of the two *Lungarni*, pedestrian and vehicular road axes that coast the river, crossed in the historic portion by 5 bridges. Additionally, a series of transverse axes to the river give continuity from the south to the north of the city, which in the upper left hosts *Piazza dei Miracoli*. It is interesting to point out that the entire area extension is just over 2.60 km^2.

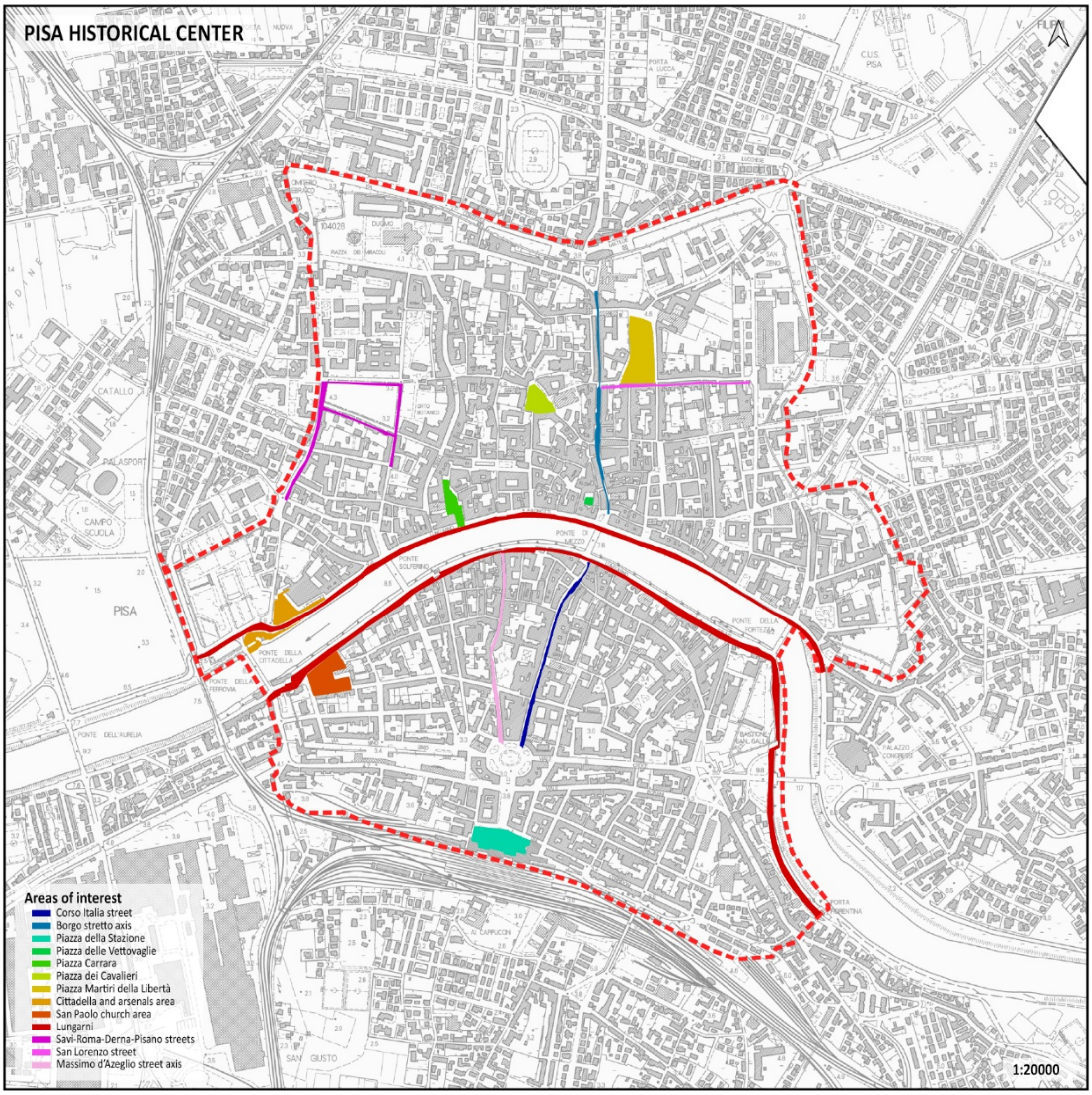

Figure 5. The historic city centre of Pisa – areas of interest

Regarding the *axial analysis*, the global integration and choice measures were evaluated as a representation of the natural movement of pedestrians within a city. In particular, an equal count subdivision for the global integration and an equal interval for the choice measure have been realised. This choice has been made by combining the need for graphic representation and the need for the integration to have a subdivision that would allow the analysis of percentage values. Instead, regarding the representation of crimes on the territory, the heatmaps obtained from the SIGR that were processed and georeferenced in QGIS 3.16 (2020) were overlaid to evaluate the chosen crimes distribution within the city (Figure 6).

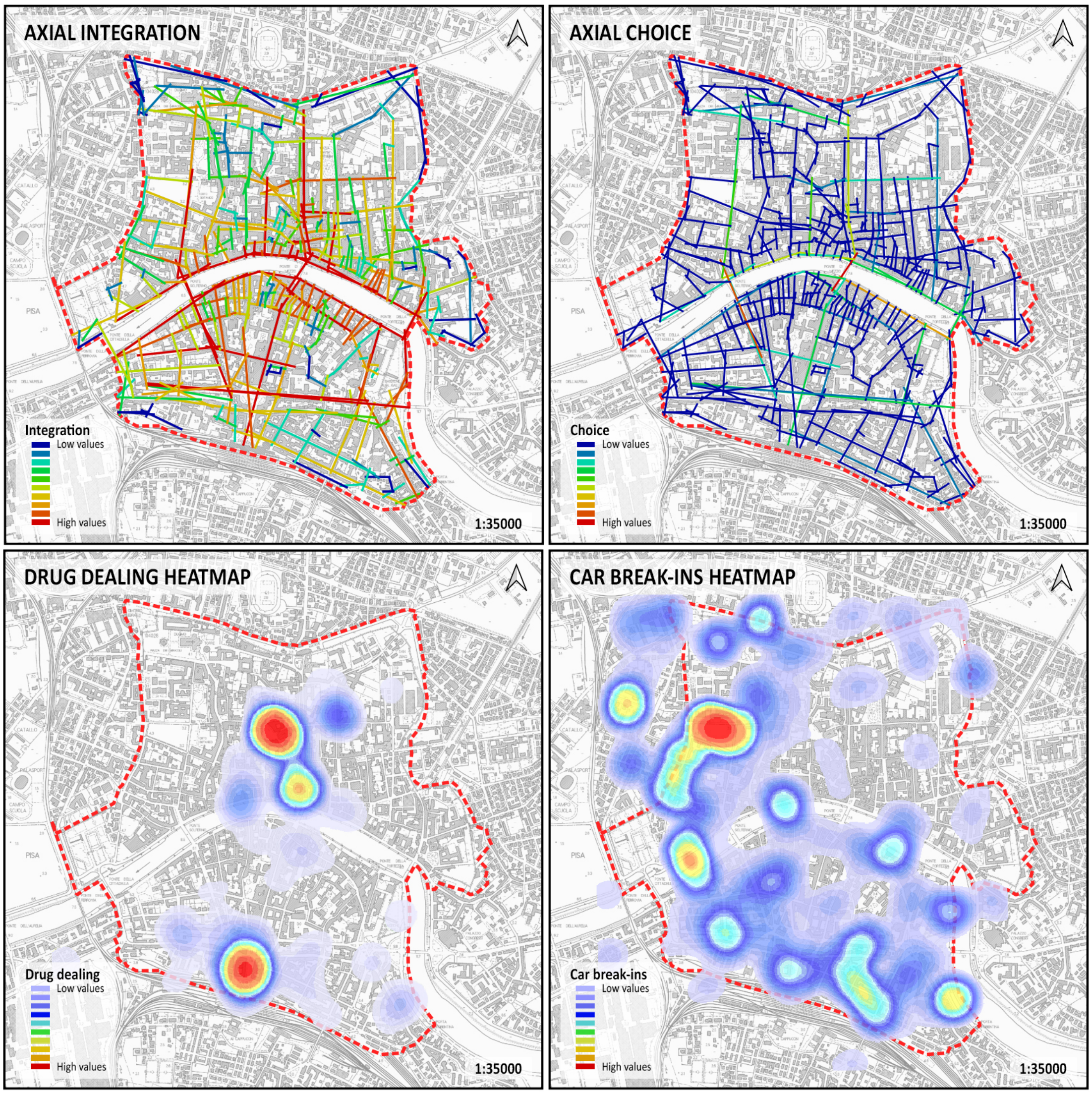

Figure 6. Axial analysis and crime distribution in the city centre of Pisa. (a) Integration (b) Choice (c) Drug dealing heatmap (d) Car break-ins heatmap

The results demonstrate that the main drug dealing spots (*Piazza della Stazione*, *Piazza delle Vettovaglie*, *Piazza dei Cavalieri* and *Piazza Martiri della Libertà*) are concentrated near streets with high values of integration and choice, and therefore with high pedestrian movement potential. Relationships of this type are less evident for car break-ins, albeit these seem to have an important relationship with the urban parking lots – such as those in the *Piazza Carrara* and *Via Roma*. Generally, car break-ins tend to be most related to areas with medium and low values of integration and choice, both at the historic centre scale (Figure 6) and at the municipal scale (Figure 4), which demonstrates that car-break ins are related to road elements that possess a lower overall movement. Subsequently, the *Visibility Graph Analysis* of the historic city centre, which denotes the values for visual control, was carried out. In fact, as already mentioned, many of the crime theories emphasise the importance of control and surveillance, considering them decisive elements in the realisation or not of crime. In this regard, the maps of visual control and visual controllability were created to understand if there were relationships between the visual component and the crime distribution.

Regarding both drug dealing and car break-ins, the offender, according to a rational action choice perspective, should look for areas where control, formal and informal is limited. The patterns that are highlighted by the VGA (Figure 7) demonstrate that, however, for drug dealing the occurrences tend to be concentrated in areas with high control and controllability.

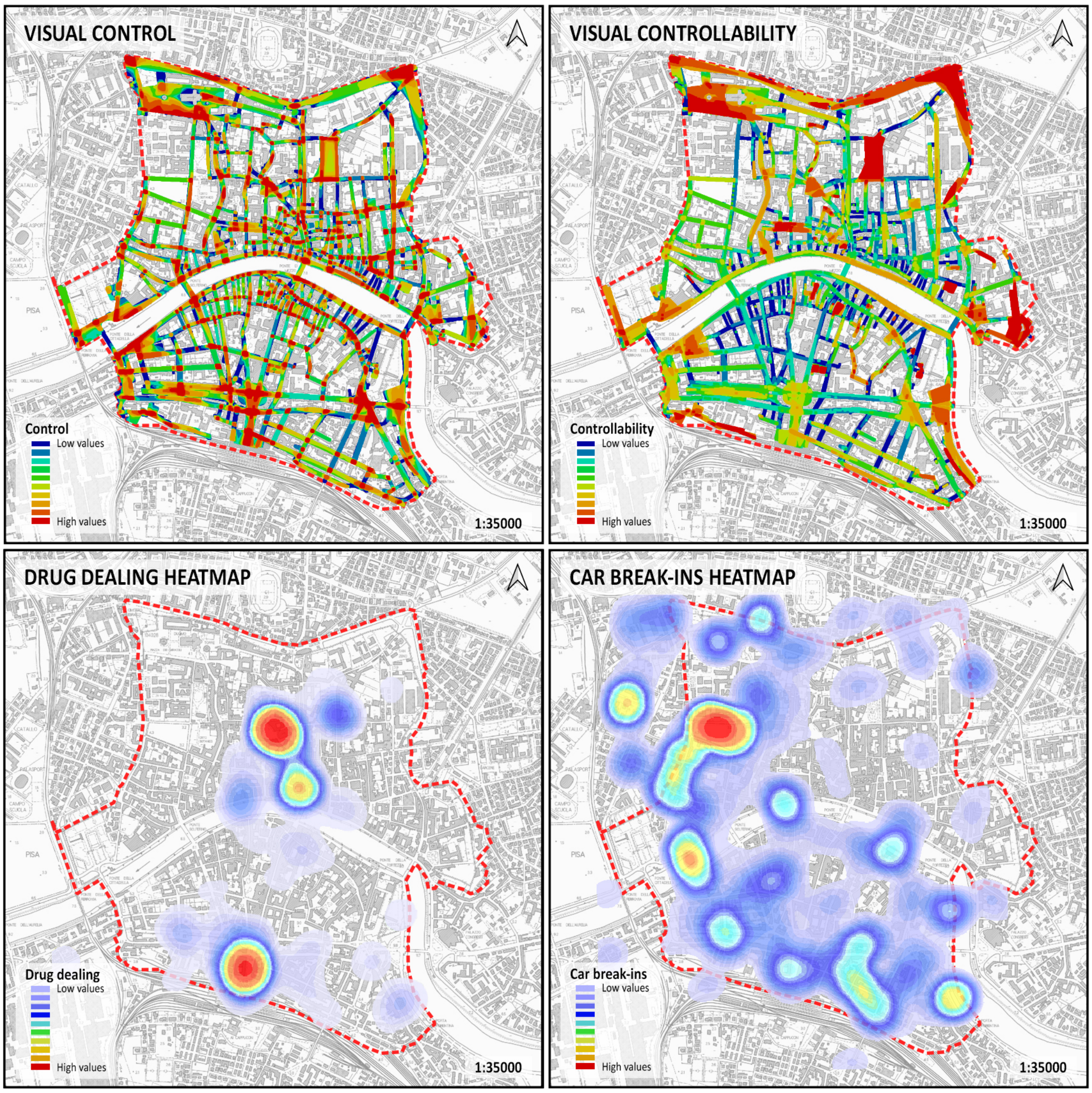

Figure 7. Visibility Graph Analysis and crime distribution Pisa historic centre. (a) Control (b) Controllability (c) Drug dealing heatmap (d) Car break-ins heatmap

Here, however, a consideration of the logical interpretation of the results is required: these areas tend not to highlight where the drug dealing effectively occurs but, instead, where the offender is caught. Then, illegal activities likely occur in areas that have low control and controllability values close to the hotspots where the offender is caught. However, this does not completely exhaust the analysis of the configurational and built aspects, as other features – such as lighting, degradation and neglect, surveillance by the police, CCTV presence and land use – play a role and can affect the rational choices of the motivated offender. In addition, the presence of elements that cannot be assessed at this scale (walls, visual barriers, trees, drops...) can also condition the crime distribution, so it will be necessary to integrate the study with close-scale studies. These aspects will be addressed in future studies. This research, as an initial study, focuses on evaluating the effectiveness of visual control measures on an urban scale, and in particular, the visual controllability measure, which has interesting correspondence with the logic of surveillance and crime. By visualizing the data maps, it emerges that the historic centre of Pisa has many narrow streets of low visual controllability at various points of the city. In particular, there is a very dense fabric of streets with low visual controllability in the adjacencies of the *Lungarni* (the riverside roads) in the central portion of the city, precisely in the streets that develop transversally from the axes of the roads that run along the river. Given this first assessment, an integrated analysis of the two types of criminal activity is proposed, namely Drug Dealing and Car Break-Ins.

4.3 Drug dealing

As already mentioned, the areas in which the crime is more diffuse are characterised by their proximity to potentially crowded areas, with high values of integration (i.e: *Piazza dei Cavalieri* - all the axes leading to it; *Piazza delle Vettovaglie* - *Borgo* axis and the *Lungarno*; *Piazza della Stazione* - *Corso Italia* and *Massimo d'Azeglio* street axis; *Piazza Martiri della Libertà* - *San Lorenzo* street). In particular, the places where this crime occurs most are squares (*Piazza dei Cavalieri*, *Piazza Martiri della Libertà*, *Piazza delle Vettovaglie*, *Piazza della Stazione*) and the streets adjacent to them. These spaces are therefore characterised by large flows of people, even during the night, being these areas are the ones where the nightlife of Pisa is concentrated, except for the station square. The value of controllability offers considerable information in the reading of crime distribution; in fact, areas with the highest incidence of crime are characterised by the simultaneous presence of crowded spaces and narrow streets in the immediate vicinity with a very low value of controllability. This type of crime combines perfectly with these spatial needs: bustling areas where supply and demand meet and close areas without surveillance, safe for drug dealers, in which to commit the crime with a lower risk of being caught in the act of selling. In fact, as already said, it should be emphasized that the geolocation of the single criminal event may not represent the actual spot – associated with high controllability areas – where the dealing occurred or occurs, but usually corresponds to the place where the drug dealer is captured by police forces or reported by citizens.

Figures 8 and 9 show the 10% of the areas with the lowest values of visual controllability and 10% of the road elements within the highest values for integration to clarify the relations analysed.

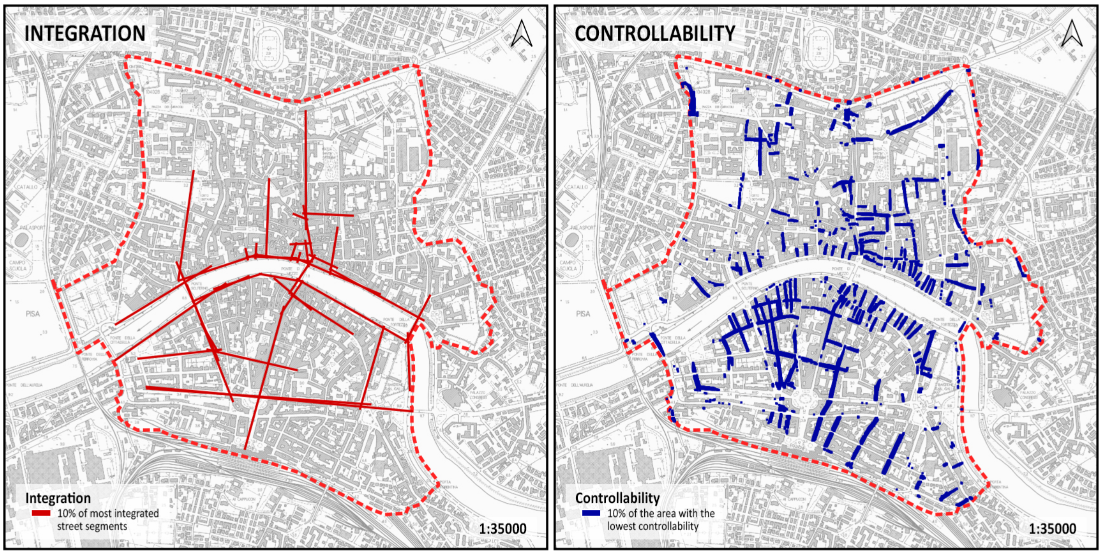

Figure 8. Pisa Historic Centre road circulation network a) 10% of most integrated road elements and b) 10% of areas with the lowest values of controllability

The areas with low values of visual controllability near spots with a high frequency of drug dealing respond in fact to the characteristics of the areas described by Cohen Felson as awareness spaces (1979), located near areas of interest and with large flows in which daily routine activities are carried out. Moreover, these awareness spaces in this specific case, due to the urban configuration, are located in areas with low controllability value, therefore obviously representing a further opportunity for the realisation of this type of crime. Therefore, these spaces can be considered crime attractors (Brantingham and Brantingham 2017): areas that for many interconnected reasons become particularly suitable for the realisation of crime.

Moreover, from an operational perspective, the visual controllability measure can provide specific information on which areas need interventions in terms of control, for example, guiding institutions in the placement of CCTV in a preventive perspective (and, secondarily, even as a repressive instrument). In fact, from the routine activity approach perspective (Cohen and Felson 1979), the presence of CCTV affects the essential conditions for crime to occur, introducing a source of surveillance, albeit passive. In this perspective, in fact, the deepening of the combination of VGA measures and new integrated technological control systems can provide significant results in the development of smart safe cities. The visual control measure instead, in the operational application of CCTV placement, allows for determining the best areas to maximise the control with the least use of cameras, optimising their positioning. These types of interventions, although certainly not exhaustive from a crime prevention perspective, can be important in discouraging criminal activity in those areas, reducing opportunities and increasing perceived risks by the offender, and at the same time possibly generating a greater sense of security in citizens. Regarding the area of the railway station instead, the dynamics are different:

although the flow is considerable for mobility issues, the area does not host many activities, especially at night, maybe increase the feeling of insecurity among citizens. This could have led to a decreasing informal social control and significant degradation of the area according to the Broken Windows Theory (Wilson and Kelling 1982). From this viewpoint, it would be interesting to investigate the social aspects and policies that have led to this condition and evaluate the elements that most affect the real and perceived insecurity.

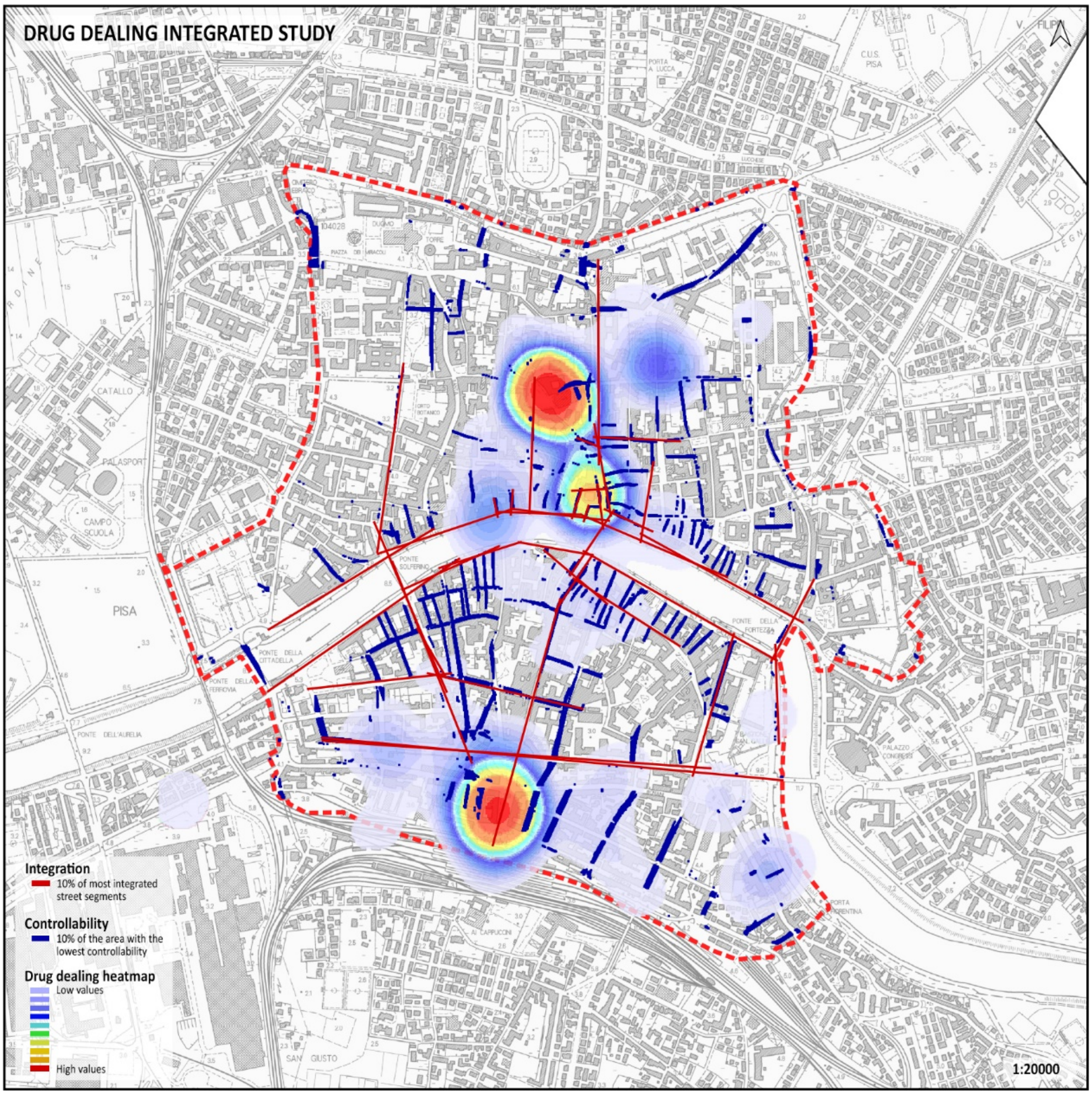

Figure 9. Comprehensive visualization of drug dealing offences distribution, 10% of most integrated road elements and 10% of areas with the lowest values of controllability

4.4 Car break-ins

The distribution of car break-ins offences is very different, influenced firstly by the location of the parking areas. However, some observations can be made, considering again the 10% of the areas with the lowest controllability values, and the 10% of the road elements with the highest integration values. Apart from the two main spots (Western *Lungarni* and the area related to *Savi*, *Roma*, *Derna* and *Pisano* streets), there is a certain correlation between the areas with low controllability values and the areas most affected by car break-ins. However, since this distribution is more homogeneously distributed, it would be more effective to make punctual evaluations, considering the street segments actually most affected, since the heat map does not facilitate the analysis. Regarding the Western *Lungarni* area and the area related to *Savi*, *Roma*, *Derna* and *Pisano* streets, an interpretative hypothesis can be formulated: the *Lungarni* are not characterised by low controllability, and it results moreover to be one of the most integrated street segments. However, that portion of the riverfront, on both sides, is characterised by the absence of apartments facing the riverfront (Medicean arsenals and the *Cittadella* area on one side, former Benedictine convent and *San Paolo* church on the other side) and by the absence of activities, that could be responsible for a poor sense of belonging of the citizens and lack of informal control.

The area related to *Savi* street has different environmental features but situations and opportunities in some ways comparable to the previous case, with streets, apparently with medium levels of visual controllability (from an urban-scale analysis) but instead with particularly favourable conditions for this crime. In fact, as for the *Lungarni*, it is possible to suppose a very low level of informal control, caused by several reasons: the absence of residences in *Savi* and *Roma* streets, the presence of physical barriers (e.g. perimeter wall of the botanical garden), the absence of pedestrian access to buildings, the general land use of the neighbourhood that especially at night, makes the area quite unattended. Moreover, there is a turnover of cars that allows renewed opportunities, being those park lots dependent on the nearby hospital.

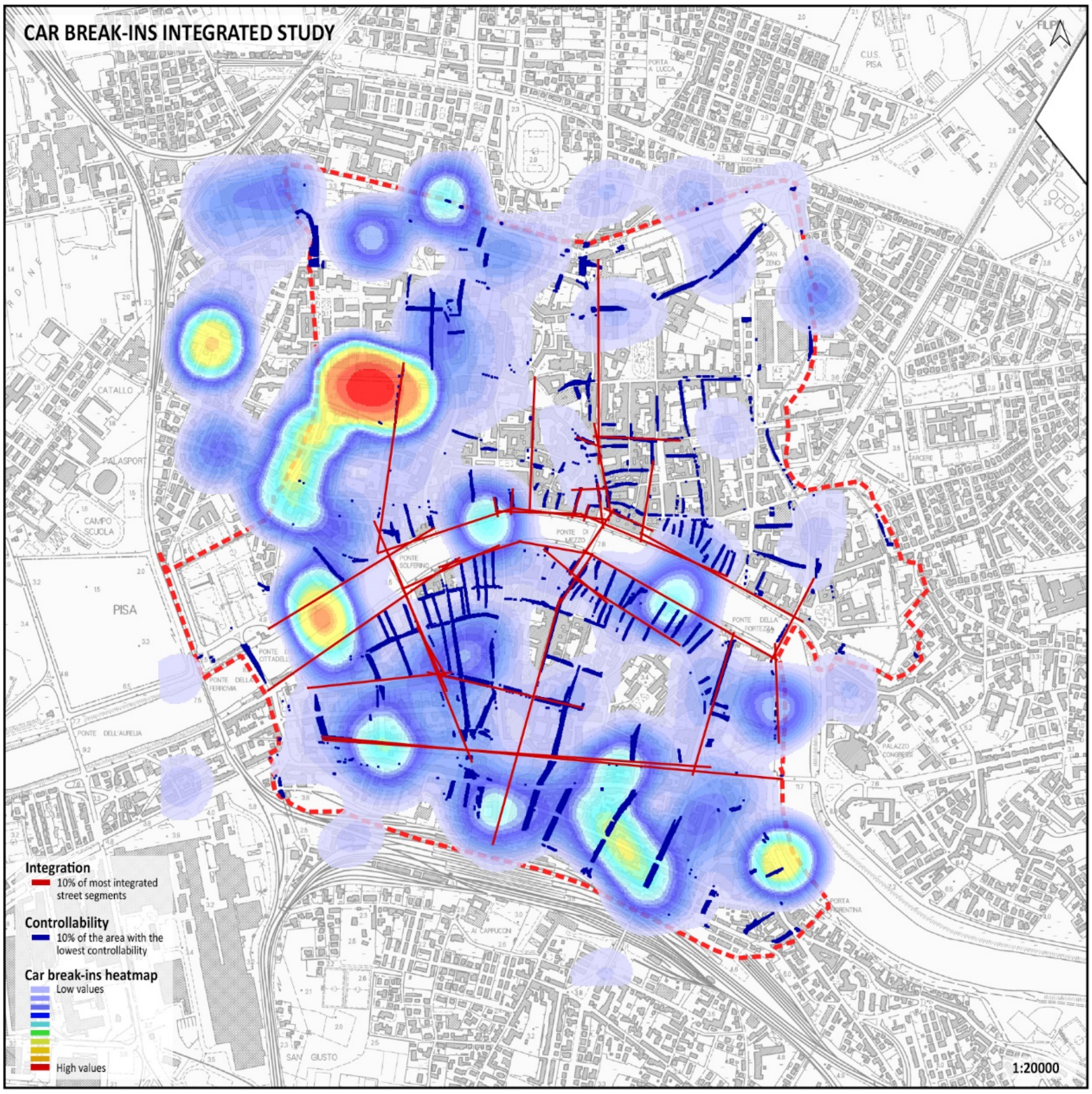

Figure 10. Comprehensive visualization of car break-ins offences distribution, 10% of most integrated road elements and 10% of areas with the lowest values of controllability

Also in this case, therefore, referring to the abovementioned crime prevention theories, some dynamics foster crime opportunities, in particular related to the absence of CCTV surveillance.

However, looking at the interpretative hypothesis made, in particular for this type of crime, a more in-depth study is needed: a quantitative analysis to understand the relationships between controllability and the most affected streets segments and the integration with other factors such as land use, temporal analysis, and micro-urban scale analysis. This could improve an understanding of the dynamics and reasons for such a distribution and, more generally, assess the impact of the neighbourhood and architectural design on crime occurrences (Van Nes and Lopez 2010).

5 CONCLUSIONS

This study has shown qualitative correlations between urban environment features - in terms of configurational and visual characteristics - and the spatial distribution of drug dealing and car break-ins crimes. In particular, it was found that the crime of drug dealing is concentrated in areas with high flows of people and close areas with low visual controllability, in line with the rational pattern of the crime. For the crime of car break-ins, the relationship between crime distribution and low controllability appears less clear at an urban scale analysis, so it is necessary to investigate possible relationships existing at the micro-urban scale considering other factors that affect control such as lighting, the presence of physical barriers and the land use. It was also observed that the visual control measure can guide towards the optimisation of any control device placement.

More generally, this study has highlighted the potential of VGA at the urban and neighbourhood level, and how, through the integration of axial analysis and visibility graph analysis, it is possible to analyse different aspects of the urban environment, which are closely related to crime distribution. The VGA in particular, used so far mainly at the architectural scale, can prove to be a very useful tool in assessing urban spaces in terms of visual fields and therefore visibility, control, and opportunity to commit (or not) a certain crime, being in a rational motivated offender perspective. In this way, it will be possible to understand what areas, depending on the urban characteristics, are more 'naturally' subject to certain crimes and guide place-specific interventions to fight crime by intervening in both control and urban regeneration. In particular, the possibility to investigate the relationship between CCTV positions and viewsheds and the *isovist* and *visual fields* (VGA) in the urban scenario from the perspective of surveillance and control emerges and represents an intriguing aspect, yet to be explored, the focus of future specific in-depth studies.

Furthermore, this study has highlighted possible further investigations. On the one hand, to investigate the above relationships in quantitative terms to analytically demonstrate the relationships observed in qualitative terms; to integrate the study with additional information on the environment to have a wider view of the aspects that affect crime distribution (CCTV position, lighting, fear of crime...); to add studies of specific areas on a micro-urban scale.
On the other hand, the possibility of expanding this study emerges through: the analysis of the distributional dynamics of other types of crimes (robberies, burglaries...); the study of possible correlations between crime distribution and other space syntax (VGA in particular) measures such as through vision and visual clustering coefficient; the deepening of temporal dynamics in addition to spatial ones. In conclusion, from the in-depth study of these aspects and the integration with other tools, further potentialities of *Space Syntax* may emerge, which, more than what it already does today, may represent a decisive tool to support decisions in urban planning in view of crime prevention.

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