Modelling Crime Dynamics and Risky Places: A Basic Combination of Crime Theories and Space Syntax to Evaluate Spatial Crime Impedance

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Abstract. Effectively modelling urban systems is challenging but necessary to obtain appropriate tools to consciously intervene in cities. Among urban subsystems, urban security plays a fundamental role – since it is closely linked to the concepts of sustainability and liveability – and it is characterised by two specificities from the modelling standpoint. The first is that it requires considerable multidisciplinary integration between neighbouring fields including criminology, sociology and urban planning. The second is the specific need to include human logic and consequently human behaviour to some extent to be able to depict crime distribution dynamics. These two aspects are crucial in the environmental approach to security, which seeks the origins of criminal behaviour in the environment. In the logic of crime prevention through environmental design, it is therefore necessary to build models with the above-mentioned characteristics. In particular, this study represents a preliminary step of a modelling investigation aiming to show how even a few simple proven assumptions – in this specific case Crime Triangle and Rational Choice Perspective – and *ad hoc* urban modelling tools – the Space Syntax theory – can provide effective modelling. What emerges specifically in this paper is the central role, at least in light of the specific assumptions made, of pedestrian movement and the concepts of visibility and controllability, which can be interpreted through Space Syntax via *Axial Analysis* and *Visibility Graph Analysis*. This proposed basic modelling is then schematically applied to the historical centre of Grosseto with reference to robbery, drug dealing and pickpocketing to offer a first spatial recognition of the inner predisposition to host certain types of crime, which we refer to as 'spatial crime impedance'.

Keywords: Environmental approach to security · Crime prevention · Space Syntax · Pedestrian flow · Visibility · Urban modelling · Spatial crime impedance · Criminological environmental theories · Decision Support System

1 Introduction

Cities are complicated and complex systems, characterised by numerous factors interacting with each other according to non-linear rules. It is therefore extremely difficult to understand the cause-effect relationships between the various phenomena occurring

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in them and, consequently, to understand what interventions should be made in the city to achieve a predetermined desired effect. This complexity has also increased over the years due to the growing needs of inhabitants and increasing urbanisation [1]. In this chaotic scenario, the role of the urban planner – who, like a 'demiurge in process', has to plan interventions in the city while trying to modify and improve the environment around us – is as difficult as it is fundamental. Considering all the sub-systems into which the city can be analysed, the minimum unit is represented by the individual to whom all implemented policies are ultimately directed and on whom they must be measured. Individual considered in his 'universality', as a representative of all the needs of today's and tomorrow's citizens – while respecting the principles of sustainability – in the awareness that planning has a decisive role for both current and future generations. Therefore, more than a demiurge, the urban planner (with the partnership of the involved stakeholders) represents a technician at the service of the community. It follows that the reflections and interventions proposed must be aimed at maximising human well-being [2]. Among the various aspects related to human well-being is certainly present – and indeed represents one of the fundamental aspects to be satisfied – the security issue. Security is intended in a wide variety of meanings but its basic dimension is represented by physical safety, as described by Maslow [3] who identified it as the second primary need for man and a fundamental component of the primordial aggregating principles of men that led first to the formation of the early tribes and then of cities [4]. Even limiting the urban investigation to crime-related dynamics, the problem of the complexity of the system to be analysed persists. Then, the first goal of urban planners must be the realization of a model able to 'schematise' reality by achieving a degree of 'acceptable' simplification. Specifically, the search for the simplest possible model able to capture the dynamics being investigated, aid analysis and ultimately provide the answers sought, considering the 'perspective' with which the problem is addressed. However, modelling applied to the field of urban security – and in particular aimed at crime prevention – brings out some specificities.

First and foremost, the multidisciplinary nature of the topic. Various fields of investigation have been interested in the topic over time, developing different and rarely effectively integrated approaches and terminologies [5, 6]. These include criminologists, sociologists, psychologists, urban planners and architects, particularly concerning the environmental approach to security, the focus of this paper. Contributions coming from different fields show how their integration is indispensable to provide plausible models capable of interpreting crime dynamics – and, consequently, crime distribution – and the impact of the urban environment on these dynamics.

Secondly, the presence and the importance of human component. Compared to other geographical models, it is here necessary to include a real human behavioural model, however simplified. This is needed to understand how individuals behave in space and according to which decision-making process crime is carried out. In general, this second aspect is strongly influenced by the scale of investigation, as is the case with most modelling problems.

The question of which characteristics spatially most influence criminal or non-criminal behaviour and, spatially, which areas are most likely to 'host' a certain crime – in relation to human behaviour – is as intriguing as it is complex. This paper constitutes a

preliminary investigation of the modelling aspects – with some preliminary results – of crime prevention through urban design topic, faced in a multidisciplinary logic. In particular, the interest of this paper is to illustrate the power of these interpretative models in understanding how, given a certain behavioural pattern, the impact of the spatial component can be assessed. Or rather, talking in configurational terms, the spatial impedance [7] that a certain environment interposes on the realisation of a specific crime. The result is a study that reduces crime dynamics interpretation to a few quantities and – as Space Syntax shows – closely related to the urban configuration: pedestrian flow and visibility. The objectives of the paper are thus to bring out the importance of crime prevention, to highlight the 'strength' of the configurational approach in the study of elements that have a strong impact on crime distribution, and to make readers reflect on how even simple models can provide very useful information on crime dynamics – hence the possibility of using these models as useful decision-support tools and preliminary studies on the urban environment in terms of 'predisposition' to crime. This is achieved through an initial theoretical discussion, the presentation of the quantities useful for such interpretations and, finally, the realisation of a basic case study applied to the historical centre of Grosseto.

2 Concepts and Methods

As anticipated, the paper is divided into two macro-sections. The first is 'revisional' (Sects. 3.1 to 3.4) while the second is 'applicative' (Sect. 3.5). The first offers a brief review of the criminological environmental approaches (Sect. 3.1): fundamental tools for interpreting criminal dynamics, with a particular focus on the rational choice perspective and the crime triangle (Sect. 3.2), chosen in this paper as a specific criminological theoretical model. Subsequently, a brief framework on Space Syntax theory analyse why and how Space Syntax represents an optimal tool for modelling flows and people behaviour in urban spaces also from a multi-scalar (urban, micro-urban, architectural) investigation perspective. Instead, in the second section (Sect. 3.5), once this multidisciplinary contextualisation has been provided, the practical applicability of these models will be discussed through the discussion of a simple case study on the historical centre of Grosseto.

3 Results and Discussion

3.1 Crime Theories

Among the interpretative models of crime distributions and human behaviour in criminal dynamics, environmental criminological theories play a key role. They represent models suitable for understanding criminal behaviour and how environmental components influence the occurrence of criminal events. Although they're different, the theories are not in contradiction but rather have several points of contact. They propose different perspectives and scales of analysis, so the choice of the crime theory that is most functional to the specific research question represents an important step. For this reason, this section offers a very quick overview of the main crime theories (for further details

and discussions see [8]) to let the reader understand the different ways in which they approach the topic. This is followed by the choice of a specific interpretative 'set', which is further explored in Sect. 3.2.

Among the main environmental criminological theories are:

- Crime Prevention Through Environmental Design (CPTED);
- Defensible Space;
- Situational crime prevention (SCP);
- Rational choice perspective (RCP);
- Routine activities approach (RAA);
- Crime pattern theory (CPT);
- Broken Windows Theory (BWT);
- Problem-oriented policing (POP).

Defensible Space and CPTED – although very different in their concept – constitute the first real scientific reflections, made in the 1970s, in the field of the environmental approach to security, after the decisive contribution of the Ecology School of Chicago first and the important studies of Wood, Jacobs and Angel later [5]. **Crime Prevention Through Environmental Design (CPTED)**, coined by the psychologist Jeffery [9] although it became known thanks to Newman [10], introduces systems thinking to the analysis of criminal behaviour in relation to the environmental inputs humans receive, combining both organic and physical sciences. In particular, he dwells on the need to focus on the brain as the centre of elaboration of external inputs and the command centre for enacted behaviour, including criminal acts. Due to the high complexity this approach proposes, it was initially neglected and then recovered over time.

In opposition, the **Defensible Space**, coined by architect Newman [10] found immediate success due to its relative simplicity and the short timeframe in which concrete results could be achieved. Newman's was a practical approach in which general considerations were drawn from some general observations of reality. This led him to the definition of four principles: territoriality, surveillance, image and milieu and geographical juxtaposition, which were identified as key aspects capable of determining safe environments and thus to which analyses, plans and interventions must be targeted.

Situational Crime Prevention (SCP), born in 1976 [11], takes up Jeffery's studies and introduces the concept of benefit-cost in the criminal field, whereby by intervening in the environment it is possible to reduce the desirability of that place in the eyes of the potential criminal. This logic is also taken up by later approaches. The basis of this approach is the implicit assumption of the reasonableness of the criminal, specified by the **Rational Choice Perspective (RCP)** formally introduced in 1985 [12], according to which the criminal objectively assesses risks and possible gains. Furthermore, in the wake of this assumption, so-called 'scripts' to fight crimes have been proposed over time [13]. Assuming the RCP and the lack of precise spatiotemporal coordinates for a certain crime occurrence, it is possible to intervene at several moments in the 'storyline' by interrupting – through environmental modifications – the chain of events that would lead to that crime, in order to prevent it from taking place. In this sense, therefore, each of the steps leading to the crime occurrence represents an opportunity for the planner to counter and remove that possibility, interrupting the 'path to crime occurrence'.

Routine Activities Approach (RAA) coined by Cohen and Felson [14] shares some aspects with the SCP, however, being characterised by a wider scale of analysis. The key principle underlying the RAA is that a crime occurs where there is a convergence of a motivated offender, a suitable target and the absence of an 'active' (i.e., able to intervene) guardian. **Crime Pattern Theory (CPT)** [15], on the other hand, focuses on the concept of opportunities considered through (and generated by) the patterns that the everyday life of each of us, collectively, generates. According to this approach, some places are more 'risky' than others – *a priori* variable with the specific classes of crime – depending on their intended use, the daily dynamics that take place there and the concentration of people. The concept of 'awareness spaces' is also introduced: well-known and frequently travelled places in the daily routine where potential criminals make assessments of the existing potential opportunities.

Broken Windows Theory (BWT), introduced in 1982 by Wilson and Kelling [16] dwells on the impact that urban disorder and soft crimes can have on fear of crime and future crime occurrences, implying a kind of self-fulfilling prediction that starting with a diminished sense of belonging to the place leads, in turn, to abandonment and to the consequent perception of those areas as 'lawless', hence the propensity to host crime.

Finally, **Problem-Oriented Policing (POP)** introduced by Goldstein [17] is more of a kind of guide that promotes a proactive approach (situational approach) to the police force system, rather than a proper theory. POP thus promotes a problem-solving and democratic approach to crime prevention, shifting the focus from the exclusively repressive realm – which had characterised the police forces until then – to the preventive one.

The approaches just described have been extensively discussed over the years and this has led to their development and updating over time (for more details see [8]). As can be deduced from the albeit brief discussion, the approaches that refer to an interpretative behavioural model of individuals or a methodology aimed at the determination of recurrences and/or situations underlying criminal actions are those shown in Table 1, namely the SCP, RCP, RAA, CPT and, in a different way, the BWT. In particular, the investigation proposed in this paper specifically deals with the Routine Activities Approach and the Rational Choice Perspective, while excluding the more advanced concept of script. This is to demonstrate how even a very basic assumption – accompanied by specific and effective tools – can help in interpreting the social impact of urban space. This combination was decided on the basis of the scale of the investigation: the urban/micro-urban scale. For this scale these approaches are particularly suitable, as they do not envisage an analysis centred on the criminal and thus too close, nor do they imply a structured analysis of activities and temporal routines, which would have required more complicated modelling (but anyway feasible). The following section delves into these 'approaches'.

Table 1. Summary of the criminological environmental theories characterized by a specific methodology or interpretative model of crime occurrences.

Theory	Seminal work and authors	Description
Situational Crime Prevention (SCP)	*Crime as Opportunity* Mayhew, Clarke, Sturman and Hough 1976	It analyses the opportunities that the environment offers to a potential offender and it focuses on environmental modifications to reduce the benefit/cost of criminal offences
Rational Choice Perspective (RCP)	*Modelling Offenders' Decisions: A Framework for Research and Policy* Clarke and Cornish 1985	It considers the offender as 'rationality-driven', who therefore decides whether or not to commit a crime by weighing possible gains and risks
Routine Activities Approach (RAA)	*Social Change and Crime Rate Trends: A Routine Activity Approach* Cohen Felson 1979	It analyses criminal opportunities based on emergence phenomena resulting from the routine habits of the inhabitants. It also introduces the crime triangle
Crime Pattern Theory (CPT)	*Environmental Criminology* Brantingham Brantingham 1981	It analyses specific classes of crime based on the inhabitants' daily patterns
Broken Windows Theory (BWT)	*Broken Windows: The Police and Neighborhood Safety* Wilson Kelling 1982	It analyses the effect that urban disorder and soft crimes may have on the actual increase in crime occurrences

3.2 Crime Triangle and Rational Choice Theory

As already said, the Routine Activities Approach (RAA) is an environmental criminological theory that explains how criminal behaviour is influenced by everyday activities and routines. According to the RAA, crime is caused by "the convergence in space and time of […]: (1) motivated offenders; (2) suitable targets; and (3) the absence of capable guardians against a violation" [14, p. 589]. This therefore suggests how crime occurrences are not solely determined by the offender's motivation but are also influenced by situational factors. When discussing this principle, the 'crime triangle' (Fig. 1) is usually taken into account.

The 'motivated offender' is an individual who has the desire and willingness to commit a crime. RAA proposes that offenders are more likely to commit crimes when they perceive the benefits to outweigh the risks. So, offenders may be deterred from committing crimes if they perceive a high risk of getting caught or facing severe consequences. The rational component of the individual is already implicitly included here.

The 'suitable target' is instead an object or person that the offender perceives as valuable or vulnerable and the RAA suggests that potential targets are more likely to be victimized if they are visible, accessible, and valuable. Please note that visibility and accessibility, key aspects according to the RAA, are two pivotal concepts of urban analysis, which will be discussed in more detail below. Targets may be objects, such as cars or electronic devices, or individuals; in particular much research [18, 19] outlines how people with poor self-defence skills such as women, the elderly, ethnic minorities, and lower-class people are more likely to be targets of crime.

Lastly, the 'absence of a capable guardian' represents the third key element of the RAA. It refers to the lack of individuals or systems that can prevent or deter criminal behaviour. The RAA proposes that capable guardians can include formal actors, such as police officers and security guards, or informal actors, such as friends and family members. This clarification of 'capable' specifies how guardians need to be proactive and have the capacity for effective immediate intervention. This therefore excludes the whole set of devices that refer to formal digital surveillance, i.e. all the various types of sensors and CCTV. The difference between 'on-field' control and digital control is a very interesting topic that will be explored in depth in the near future. Instead, in this discussion, we merely point out how the presence of CCTV combined with the offender's rationality principle should act as a deterrent – where it is common ground that CCTV is actually and effectively used for investigative and repressive purposes. In any case, there is no question that the lack of a 'capable' guardian makes a big difference in the realisation of the crime. It should be noted, therefore, how the presence of a capable guardian is related to the flows and to the compresence of people in the environment. This, when studied at the urban or neighbourhood scale – as is the intention of this study – directly refers to the study of transit pedestrian flows.

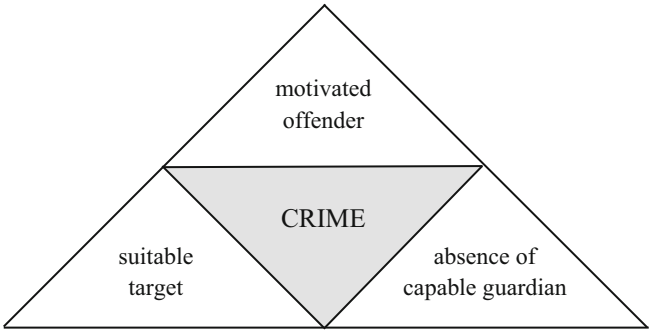


Fig. 1. Schematic representation of the crime triangle.

So, what are the assumptions of the above analysis from a modelling point of view? We assumed a simplifying law: crime occurs if there is the convergence of three elements. Then, full rationality of the offender was assumed. Then, the importance of flows – namely the co-presence of people who can potentially intervene and foil an attempted crime, thus making the crime commitment less attractive – in assessing the predisposition of an environment to crime emerged. The fundamental importance of visibility also

emerged, as large flows in an area with visual barriers do not allow the crowd, the suitable guardians, to guarantee a possible 'defensive' intervention able to foil the crime and thus perform the deterrent function mentioned above. The importance, therefore, of being able to detect flows and visibility as characters capable of giving a measure of spatial crime impedance in the analysed environment emerged. It is therefore necessary to analyse the modelling tools that can be useful in interpreting the environmental component and thus provide useful information on the interventions to be made on the environment to deter specific criminal actions. In our case, therefore, all that remains is to choose a modelling tool from the toolbox that allows us to evaluate the aforementioned aspects, and Space Syntax perfectly meets our needs, as will be discussed in the following paragraphs.

3.3 A Matter of Flow and Visibility: Space Syntax

Space Syntax represents an optimal tool for investigating the aforementioned measures. It analyses the immaterial variables of a physical space through the reading of the various elements that compose it and their reciprocal relationships, thus enabling the understanding of otherwise hidden phenomena [7]. Space Syntax overturns the logic according to which space is the inert scenario in which things happen; it is instead the configuration of urban space that defines "the material preconditions for the pattern of movement, encounter and avoidance which are the material realization – as well as sometimes the generator – of social relations" [20, pag. ix]. Leaving aside an appropriate in-depth study of configurational theory, only a very brief reminder of the underlying logic, which is intrinsically linked to the concepts of flow and visibility, is provided here. For more in-depth information on the theory, the reader could refer to [20–22].

Space Syntax, which refers at the same time to the theory of interpretation of urban space and to the set of measures that allow for it, traces evaluations of spatial impedance back to a measure of a topological nature, that is the 'visual distance' that connects two points in urban space [7], thus introducing a typically human perceptive measure in the interpretation of the built environment. While the 'intrinsic measures' refer to the urban grid as the 'negative' of the built part, the cardinal concepts of the 'extrinsic measures' of urban space [23] are the convex space (convex map), the axial sightline (axial map) and the isovist field (visibility graph).

For convex analysis, see chapter 3 of The Social Logic of Space [20]. It is interesting to observe instead that the **axial map** is the reduction of space to visual lines, and in the case of the 'fewest-line axial map' [24, p. 425] the fewest and longest lines capable of describing space. This 'new grid', made up exclusively of the fewest and longest lines, permits axial analysis with the calculation of its quantities. These can describe the preferential routes of pedestrians travelling through those environments. The main ones are Integration (closeness) and Choice (betweenness), being also the ones with the greatest capacity for estimating pedestrian flow [25]. A strong correlation between sightline and movement thus emerges, as if this grid of optical axes represented a very reliable measure of spatial impedance in the interpretation of human behaviour. It is clear how a user's movement in urban space is determined by the way the user visually perceives urban space. Thus, the concept of the isovist field, linked to the concept of viewshed, is perhaps even more immediate due to its even more intuitive representation. However, the key to understanding both the **visibility graph** and, consequently, visibility

graph analysis, is to realise that the essential element to which the grid is reduced is neither a convex space nor a linear element, but a vertex [26]. According to this logic, therefore, for each vertex of the urban grid a set of points in direct visual connection will be identifiable, which takes on the name of isovist [27–29]. Visibility graph analysis also develops a set of measures, largely shared with axial analysis but also with some specific quantities [30]. Furthermore, among the differences that can be found there is, for example, the VGA's characteristic of being able to give a visually more impactful representation – which is more detailed due to the possibility of defining the vertex dimension [31, 32] – and in some cases even outperforming axial analysis in the analysis of pedestrian movement [33].

With these few basics, the next section aims to shed light on the significant variables in assessing the susceptibility of the urban environment to certain crimes based on the assumptions made in the previous paragraphs.

3.4 More Than It Appears: Discussing Space Syntax Tools

With reference to the chosen environmental criminological theory, the Space Syntax theory with its set of measures proves very useful. In fact, we have said that the crime triangle is based on flows and visibility, and Space Syntax proves capable of effectively analysing these two pieces of information from space, extracting these intrinsic characteristics implicitly contained therein. The useful quantities to assess the spatial and configurational (so, natural) aptitude to host certain types of crimes, under specific assumptions, are now presented.

We understood in the previous section the different nature of axial maps versus visibility graphs and the different types of information they provide. As already mentioned, in this study we are interested in the flow and visibility aspects. However, we also have two additional important pieces of information to take into account when choosing the most functional analyses and measures. First, we are referring to a space of limited extension, at a scale that could be defined as micro-urban or, at most, urban. Second, we are interested in investigating the distribution of pedestrian flows.

With reference to the first point, the literature shows that VGA has historically been used specifically in the architectural field. However, under certain conditions - such as the presence of orography with negligible slopes and the realisation of a particularly detailed origin map that includes all 'visual obstacles' - VGA can be used at a micro-urban or urban scale [34] given also its 'finer granularity' of analysis compared to the other analyses offered by Space Syntax [32]. Thus, in terms of scale, both axial analysis and visibility graph analysis are usable and appropriate.

With regard to the second point, on the other hand, it is necessary to evaluate which types of analysis can best represent pedestrian movement. As testified by numerous studies [35–37] the configurational approach proved valid in estimating pedestrian movement, showing correlations between 55 and 75 per cent. In particular, it is believed that angular analysis (introduced by Turner [22] can more accurately estimate pedestrian movement. We therefore opt in this preliminary study for *Angular Segment Analysis* (ASA) and *Visibility Graph Analysis* (VGA) wanting to refer to the urban scale or below.

The quantities useful for detecting the above-mentioned information of interest are now specifically presented, indicating what exactly they represent from a mathematical

and interpretative point of view. In particular, the quantities useful for assessing movement are integration (closeness) – obtained from mean depth – and choice (betweenness), which can be calculated, as mentioned, from both the axial map and the visual graph. However, connectivity could also be logically significant in the interpretation of criminal incidents, especially if weighed in some way with integration/choice (that is to say, with existing pedestrian flows). In fact, connectivity represents the number of segments connected to each segment of the network, which can therefore be interpreted as possible escape routes for a possible criminal, being then a crime incentivator index. On the other hand, it can also be interpreted as probable gateway for the arrival of new unforeseen 'guardians', which could therefore discourage crime commitment. This specific investigation, however, is postponed to future studies. As far as the VGA is concerned, the significant quantities of visual control and visual controllability are also presented, which are directly linked to the concepts of visibility and surveillance, as well as through vision, which is instead linked to the determination of the potentially busiest areas – and can therefore be used to support Integration. Summarising, then, the quantities taken into consideration here are:

- Angular segment integration/total depth;
- Angular segment choice;
- Visual integration/mean depth;
- Through vision;
- Visual controllability;
- Visual control.

We will omit here the in-depth explanation of the differences between axial analysis and angular analysis (for which please refer to [7, 22, 25], just remembering that angular analysis, taking into account the angle generated between the various axes into which space is decomposed, also 'weighs' the paths with respect to angular spatial impedance, then interpreting human behaviour whereby between two alternative paths a person would choose the one characterised by a 'smoother', less angular course [7]. The following is a quick comparison between visual mean depth (and consequently visual integration), through vision, visual control and visual controllability.

The **visual mean depth** represents the spatial impedance, that is the effort that has to be made to reach a given point in space from an origin point in space following the shortest path. This measure can be calculated in terms of visual, metric or angular distance [30]. However, like axial mean depth, visual mean depth depends on the size of the system. This makes comparisons between different systems problematic. In order to overcome this problem, Integration measures were created by calculating Relative Asymmetry (RA) and Real Relative Asymmetry (RRA), for which we refer to [20]. In particular, there are three different integration quantities: Visual Integration [HH], Visual Integration [P-value] and Visual Integration [Tekl]. Although Visual Mean Depth showed a higher correlation with pedestrian movement in the study by Koutsolampros et al. [30], Visual Integration [Tekl] – which in any case showed a very good correlation in the aforementioned study – will be used in this study (Sect. 3.5) for similarities and simplicity of visual comparison with Segment angular Integration. In particular, the greater the Integration [Tekl] values of a given space, the greater the pedestrian flows.

The **through vision**, introduced by Turner [25], represents the number of visual lines that cross a given vertex – and thus, by extension, location. It offers a hierarchisation of existing spaces on the basis of the number of isovists passing through them, thus also being interpretable as a magnitude of movement potential [30]. It highlights the vertexes (locations) that are most likely to be crossed because they find themselves in many paths.

The **visual control** was defined by Turner in 2001 [38] from the Control measure coined by Hillier and Hanson 1984 [20]. It consists of the value obtained by "summing the reciprocals of the neighbourhood sizes adjoining the vertex" [39, p. 6]. Specifically, the greater the number of cells visible from a given cell compared to the cells visible from the cells within the visual field of the former, the higher the value of the control. In this way, the space is hierarchised according to the potential of control over the surrounding neighbourhoods, thus highlighting the visually dominant areas [39].

The **visual controllability**, also introduced by Turner [38], is expressed by the ratio between immediate visible cells and the sum of all visible cells from immediate neighbourhood cells. This translates into a metric of how much space a cell sees in comparison to the isovist of its immediate neighbourhood cells, in which the more controllable a cell is, the higher the controllability value will be. Ultimately, therefore, space is hierarchised according to how much each of its vertices (and, by extension, locations) is 'naturally' controllable in comparison to the surrounding environment. For a detailed summary of these measures please refer to [30].

At this point, it is clear the framework and the information that the chosen Space Syntax analysis and measures can provide. Next paragraph will show how they can help the interpretation of areas naturally predisposed to host certain types of crime.

3.5 A Basic Spatial Crime Impedance Evaluation Tool

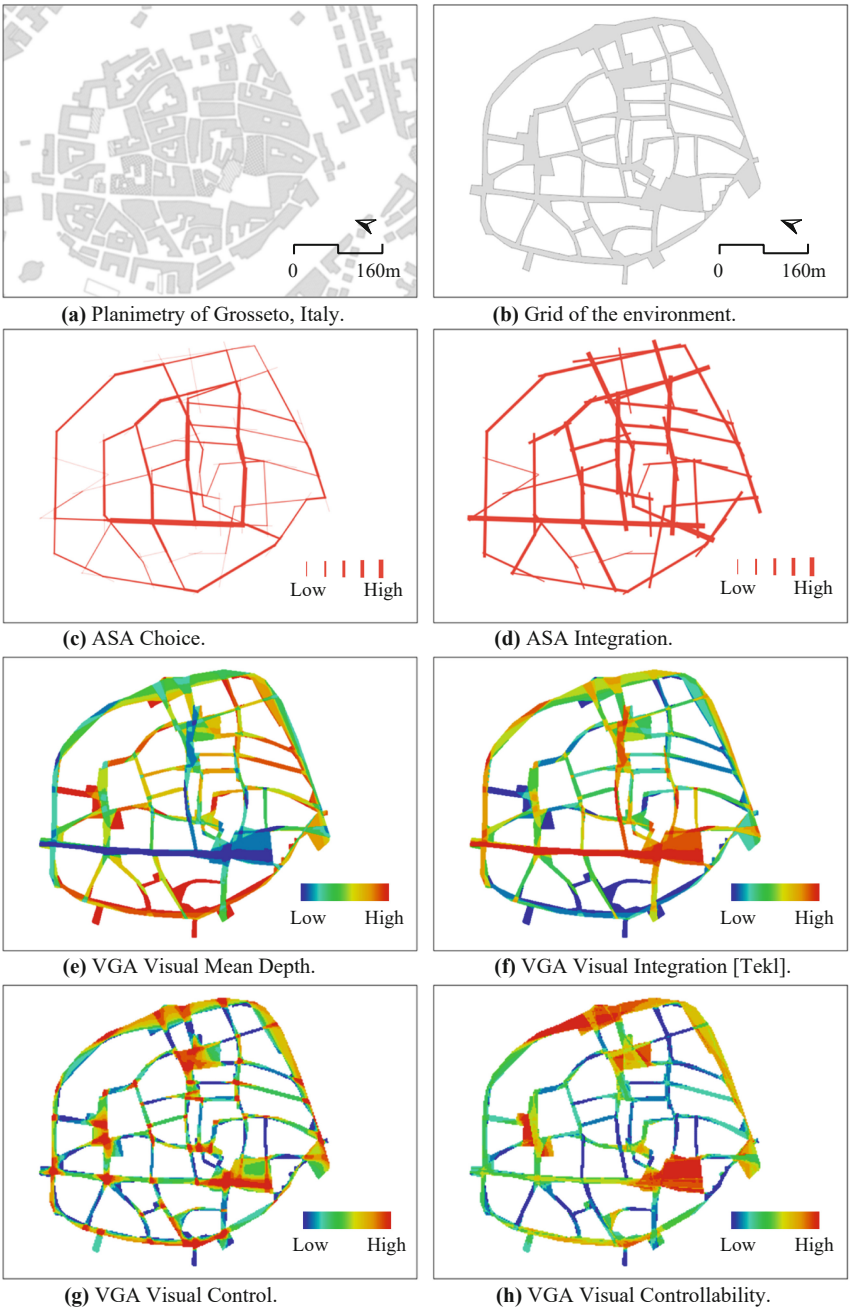
The preceding paragraphs drew all the necessary references. We chose a criminological interpretation key: the RAA, and in particular the crime triangle, together with the RCP. We selected the appropriate tools to assess the aspects suggested by the chosen criminological approaches (namely flow and visibility): *Angular Segment Analysis* and *Visibility Graph Analysis*, and in particular the Integration, Visual control and Visual controllability measures. Let us now see how these measures can provide important information on the 'susceptibility' of an environment to host crime occurrences or, using the configurational background, the spatial crime impedance. An inescapable premise: each type of crime follows a certain logic, always assuming the rationality of the offender. Although each crime is always linked to the combination of suitable target and guardian absence, it must be said that a crime such as pickpocketing and robbery, for example, have different 'boundary' conditions. In fact, the pick-pocketer will recognise in the crowd a possible hiding place and an opportunity to approach the target in an almost unsuspected manner. So, in that case, the lack of control will be given by the large number of people, for example. Vice versa for robbery, where the offender will look for isolated places with low flows of people so that he can easily avoid potential unexpected 'guardians'. According to this logic the analysis of the selected environment are conducted (Fig. 2).

The environment represents the historical centre of Grosseto, which corresponds to the portion of the city within the walls (Fig. 2a, b). The analyses were carried out with the software Depthmap X 0.8 and *Axial Analysis* and *Visibility Graph Analysis*

were processed. Regarding the grid reduction of the system, for the Axial Analysis the *Angular Segment Analysis* obtained from the Fewest-Line Map (Minimal) was used. For the *Visibility Graph Analysis*, on the other hand, a 1*1 m eye-level grid (visibility) was chosen. In particular, angular integration, angular depth and angular choice as regards ASA and visual integration, visual depth, through vision, visual control and visual controllability as regards VGA were calculated and analysed. However, the measures chosen for discussion were reduced to those in Fig. 2. As discussed in the previous paragraphs, both ASA integration and choice and VGA integration and depth offer a measure of pedestrian flows. The hierarchy of the network emerges clearly, highlighting which sections are affected by greater or lower flows. ASA Choice (Fig. 2c) highlights how the largest flows are concentrated along three segments: Corso Giosuè Carducci, Via degli Aldobrandeschi and the continuation Via dell'Unione, Via Garibaldi. ASA Integration (Fig. 2d) confirms this hierarchy, even if the final stretch of Via Garibaldi acquires greater weight together with the Stretto Corsini, which cuts it crosswise. Consequently, by analysing the thinner segments of the network, the segments characterised by lower flows are identified and thus, from the perspective of the chosen theoretical model, characterised by the presence of fewer potential 'guardians'. The VGA reaffirms the aforementioned hierarchies in a more readable manner: it makes the streets of the urban agglomeration more evident – thanks to the vertex representation, as already mentioned – and let the interstitial spaces and squares emerge here, which are difficult to perceive in the ASA. The hierarchies are confirmed and further clarified by the Visual Depth (Fig. 2e) and Visual Integration [Tekl] (Fig. 2f), bringing out even more the areas affected by large or scarce pedestrian flows. However, the VGA is also able to provide a picture of the best areas for efficient control through the measurement of visual control (Fig. 2g), which could be used in the evaluation of interventions aimed.

at security (CCTV arrangement, police patrols, location of activities…) or at least surveillance. However, we will omit these aspects in this discussion. In fact, the measure of greatest interest for the model constructed above is the visual controllability (Fig. 2h), which highlights which areas are naturally – exclusively due to the way the space is constructed – subject to poor visibility, i.e. more 'hidden'. It emerges how large open spaces have high controllability values as much as a clear hierarchy. With that, locations with lower controllability values are highlighted, which are of particular interest for understanding crime dynamics.

Let us assume, for example, that we want to evaluate three specific classes of crime: robbery, drug dealing and pickpocketing. While assuming for each of them the logic described by the crime triangle and the full rationality of the offender, it is necessary to note that the specific rationales for each crime are different insofar as they are linked to the concepts of copresence and visibility (Fig. 3). Particularly suitable locations for a **robbery** will in fact be those characterised by low pedestrian flows, i.e. a low possibility of running into 'guardians', and low controllability values, i.e. locations that are naturally not visible from the surrounding areas. As already mentioned, in the case of robbery the measure of connectivity could be a further useful element in assessing the environment. The rationale and then the expected distribution is different for **drug dealing**, for which it is generally necessary to locate oneself in the vicinity of large flows of people that allow the offender to intercept the demand and, subsequently, identify an area sufficiently



(a) Planimetry of Grosseto, Italy. **(b)** Grid of the environment.

(c) ASA Choice. **(d)** ASA Integration.

(e) VGA Visual Mean Depth. **(f)** VGA Visual Integration [Tekl].

(g) VGA Visual Control. **(h)** VGA Visual Controllability.

Fig. 2. **a**. Planimetry of Grosseto, Italy. **b**. Grid of the environment. **c**. ASA Choice. **d**. ASA Integration. **e**. VGA Visual Mean Depth. **f**. VGA Visual Integration [Tekl]. **g**. VGA Visual Control. **h**. VGA Visual Controllability.

sheltered from 'guardians' to commit the crime. It follows that the naturally risky areas, according to the chosen model, will be those with minimal controllability in the vicinity of areas with high integration/choice values, perhaps squares or main walkable streets. Finally, a specific consideration for the crime of **pickpocketing**, for which the logic changes considerably. In this case, in fact, it is precisely the large number of people that creates the anonymity needed to be able to approach and snatch a 'suitable target' inconspicuously. It is precisely the crowd that generates the lack of surveillance, the lack of 'guardians' necessary to be able to commit a low-risk crime action. Therefore, it is the areas that naturally host large numbers of people that are the riskiest in terms of pickpocketing occurrences.

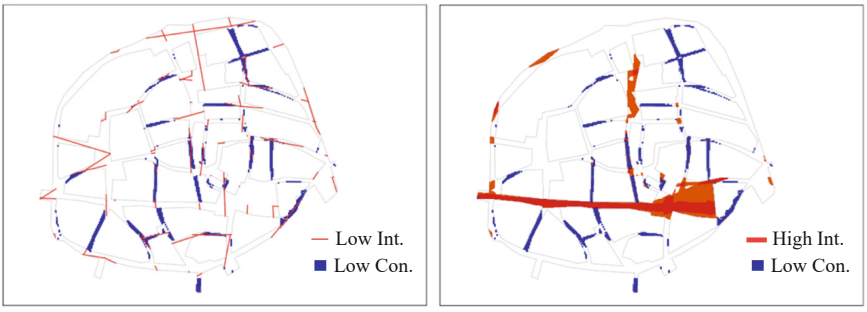


Fig. 3. Combination of significant measures to determine risky areas: 10% less integrated segments in red [ASA Integration] and 10% lowest controllable areas in blue [VGA Visual controllability] (a); 20% most integrated areas in red [VGA Visual Integration] and 10% lowest controllable areas in blue [VGA Visual controllability] (b).

4 Concluding Remarks

This study presented a basic modelling approach aimed at determining crime dynamics and risky places within urban environments. In particular, it showed how even through basic assumptions and the use of specific suitable modelling tools, it is possible to obtain interesting first assessments of the environment and what the authors defined as its natural spatial crime impedance.

In particular, it was first highlighted the possibility of developing a simple methodological approach useful for the development of new interdisciplinary models, developed through the following steps: choice of a theory of criminal interpretation and/or a basic behavioural model; study of the 'environmental' magnitudes implicitly linked to the chosen model; search for a suitable instrument capable of detecting and measuring these magnitudes; evaluation of risky places. Of course, this is only a rough outline, which may vary according to the specific choices made: for instance, in the case of this paper, it was necessary to distinguish the specific logics that guides the commission of certain crimes. This model also shows how through a conscious 'assemblage' of knowledge

from different fields it is possible to create innovative basic effective modelling tools that can serve as very useful decision support tools in preventive terms, for the evaluation of future alternative design scenarios or as a guide for the optimisation of the layout of CCTV or sensors to obtain data on cities and citizens in the perspective of an integrated safe-smart city.

Secondly, the power of the model in assessing spatial crime impedance on the basis of two fundamental quantities such as pedestrian movement and visibility emerged, which can be optimally interpreted with the aid of Space Syntax theory from the urban form alone.

This paper, however, represents only a first step of a broader modelling investigation. The application to the historic city centre of Grosseto is a schematic demonstration that needs further investigation, such as: verifying the results of the spatial crime impedance with the real crime distribution in Grosseto; repeating this approach on other urban environments and comparing the results; evaluating the impact of the integration with further spatial information that is theoretically correlated with the crime distribution, such as the distribution of activities, the presence of physical barriers or CCTV, and night lighting, from which the need for an inter-scalar approach to the problem of urban security emerges. This model also lacks the temporal component - similarly to what was highlighted last year here at ICCSA by the authors [29] – although it remains to be seen whether in this case this refinement can generate better responses in modelling terms, taking into account the KISS modelling rule. In general, these types of tools are often undervalued, relying instead on numerical or aggregate data. However, appropriate models in this field have numerous advantages with a considerable impact on decision-making administrations and, consequently, on communities, such as: eliminating or at least mitigating perceptual aspects of the environment in the determination of risky places and the prioritisation of interventions, reducing subjectivity and working towards the real resolution of problems; allowing the evaluation of alternative scenarios and the fallout of planning choices in terms of security, as well as the optimisation of the technological instrumental disposition on the territory, as already mentioned; allowing the correct evaluation of areas unknown to the planner, having an initial picture of the areas in terms of natural predisposition to certain types of crimes and even allowing a real evaluation of areas where there are no databases on crime distribution. For all these reasons, the authors believe that modelling for urban security purposes is a field to be strongly explored by the scientific community in order to provide tools to help realise liveable and sustainable cities in compliance with the goals of the EU SDGs.

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