

Digital City-Surveillance Models and Urban Security: Integrating Isovist and Space Syntax in Realising Adaptive Decision Support Systems

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Abstract. Urban security plays a fundamental role in achieving sustainable cities. The environmental approach to security proved crucial, with its inner multidisciplinarity, in fighting crime and in promoting crime prevention through environmental design, urban management and situational-oriented strategies, where the importance of surveillance emerges. Among the research fields involved, digital technology has a primary role in the research progress both through the development of advanced analysis and decision support systems (DSS), and through the elaboration of high-tech interconnected devices in a smart-safe city logic. In this vein, the paper first reviews the IT and ICT role in urban security progress, and then it traces the development and the importance of surveillance by focusing on the isovist and the space syntax theory until their last findings. Finally, the paper suggests a schematic proposal of a digital surveillance-city model based on the integration of those concepts, which could be used for analytic, decision support and predictive purposes. The strength of this model resides in its adaptability to different contexts and its potential independence from sensitive data, which permits overcoming privacy issues. Moreover – being surveillance and visibility features that impact different urban life aspects – this model could represent an urban planning DSS for strategies that goes beyond the mere crime-fighting. Furthermore, this model constitutes a first step in the development of a surveillance-oriented Agent-Based Model.

Keywords: Urban security · Crime prevention · Environmental approach · Surveillance · Digital technology · Isovist · Space syntax · Decision support system

1 Introduction

Urban security is a fundamental factor that affects citizens' quality of life [1, 2]. Since the '90s the impact of crime on citizens' well-being has been recognised and has thus become one of the main objectives of the world's leading organisations, also becoming part of the EU SDGs [3]. Even though crimes in urbanized cities are constantly decreasing [4], the perception of insecurity is still very high [5]. Sometimes the fear of crime, which is a fundamental aspect in determining citizens' behaviour and city-life [6, 7], is even

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increasing due to the growing size and complexity of cities, some collateral phenomena and the so-called urban-fear paradoxes. It is therefore necessary to continue investigating how to intervene to reduce both crime and fear of crime to achieve safe and sustainable cities. The topic is inherently complex, being generated by the combination of two complex systems such as the urban dynamics and the criminal logic, which determines the unavoidable need for multidisciplinary studies. Thus, much research has addressed the issue from different perspectives, greatly enhancing the knowledge of crime dynamics and, as a consequence, crime prevention. However, such studies were often developed with a 'tunnel vision', without deep collaboration and integration between different fields. This lack of collaboration generated problems of oversimplification, overlapping, inconsistent language and chaotic development [1, 8, 9].

The main fields involved in this research were sociology, criminology, psychology, architecture and urban planning, which between the '70s and '80s gave birth to the social approach and environmental approach to security, in addition to the traditional one that was already existing [10]. In particular, the environmental approach to security in the last decades is getting new lifeblood from the digital technology evolution: on the one hand, the technology progress allowed analysis and modelling progress, useful to confirm and validate or refute existing theories, thus allowing the scientific evolution and at the same time being used as decision support tool. On the other hand, from the operative point of view, it generated tools and devices aiming at quality-of-life improvement and citizens' safety in a smart-safe city logic. The connection between the theoretical and practical development produced advanced security systems aimed at safer cities. However, these security interconnected systems still leave many shadows and open questions about privacy concerns and data retention issues, psychological perception of citizens and social effects.

Over time, for example, the concepts of smart and safe cities have developed, based on the resource's optimization logic and the use of technology aimed at citizens' quality of life improvement. Whit this aim much progress in developing advanced systems and devices has been done. In particular, concerning safe cities and crime prevention techniques, surveillance plays a fundamental role [9]. For this reason, the theme of visual surveillance is explored in this paper. In fact, many studies show how the spaces that surround us affect our behaviour and, in particular, how the visual scenarios that open up to us, step by step, condition our subsequent choices, for example, in determining a path [11] or deciding whether or not commit a crime [12, 13]. Therefore, the integration of spatial, urban planning and criminological knowledge, with the support of digital technology development can open new scenarios in fighting crime in a surveillance and crime-reduction logic. Moreover, this joint collaboration could play a decisive role in decision support tools development for urban planning processes, for example by fostering rational choices between alternatives. In particular, this paper aims to illustrate the potential of integrating environmental criminology, isovist analysis and configurational analysis (namely the Space Syntax theory) in the development of a digital city-surveillance model as crime-fighting decision support tool. The process is here presented conceptually, and it will be the subject of subsequent applications and in-depth studies.

2 Concepts and Methods

The investigation methodology is developed in two stages (par. 3.1 to 3.4) preceding the presentation of the proposed schematic model (par. 3.5). These two sections consist of brief literature reviews of the topic on which the model is based. The first deals with the importance of the environmental approach to security (par. 3.1) and the fundamental role of digital progress in urban security theoretical and practical advancement (par. 3.2), shown through the reconstruction of the emblematic crime patterns investigation strand. The second one deals with the importance of surveillance, first through an analysis of the current situation in terms of digital surveillance tools and technologies (par. 3.3), and then through a theoretical reconstruction of the visual surveillance foundations (par. 3.4). Finally, as already said, an adaptive digital city-surveillance model aimed at elaborating crime prevention and urban planning strategies is presented.

3 Results and Discussion

Digital technology development has allowed great progress in the elaboration of tools and devices able to promote urban security from multiple points of view: in the theoretical advancement through the experimental verification of crime theories and their consequent modification and integration; in the elaboration of new models to aid planning and urban design; and eventually, from the operative point of view, with the elaboration of technological tools aimed at increasing security in cities through prevention, control and finally repression. These paths seem to be parallel and disjointed, but they are instead closely related, and their boundaries are very blurred, as this review shows.

3.1 Environmental Approach to Security: Origins and Development

The security issue is very ancient, linked to the primordial needs of the human being [8, 14] and closely connected to the primordial need that brought the formation of human settlements first and cities then [15]. However, the city has lost over time its original securitarian image, even reaching today the appellations of ‘crime generator’ and ‘place of insecurity’. Based on these premises and driven by the citizen’s growing demand for security, studies on the origins of criminal behaviour from the environmental point of view spread. Environmental criminology then developed, starting from the systematic study of the relations between urban configuration and security. The original contributions date back to the ‘60s [16–18] and ‘70s [12, 19], whose roots lie in the maps of Guerry [20] and Quetelet [21], and in the ecology school of Chicago [22, 23]. These original studies opened up a whole new scenario. The first criminological studies were mainly based on psychological and biological investigations, seeking, for example, correlations between criminal behaviour and physical characteristics. Environmental criminology shifts the focus and integrates a new element: the environment, intended in both its physical and situational interpretation. This led to the development of the not obvious idea that the modelling, organisation and management of space can influence criminal behaviour. On this basis, the so-called crime theories were developed: theories that seek to analyse the spatial and situational components that favour crime

occurrences [24]. To mention some of the main ones, there are the Situational Crime Prevention (SCP), Routine Activities Approach (RAA), Crime Pattern Theory (CPT), Broken Windows theory (BWT) and Rational Choice Perspective (RCP). These theories are complementary, with blurred boundaries and multiscalar. They have developed over time through modifications, integrations and experiments, and offer interpretative models for understanding the criminal phenomenon. In their theoretical development, IT and technological progress had a role and, in particular, ICT has proved fundamental. Analysing, for example, the so-called crime patterns investigation strand [24], the role of IT and ICT in allowing progress in research could be easily understood.

3.2 The Role of IT and ICT in Urban Security Progress

The crime patterns investigation strand consists of the Routine Activity Approach (RAA) and Crime Pattern Theory (CPT), where the latter actually integrates the geometry of crime, the RAA and RCP. Rather than a deep theoretical discussion of this strand, this paragraph focuses on the role that ICT has played in its development.

Crime pattern investigations developed from the maps of Guerry and Quetelet, which investigated socio-demographic and transport infrastructures' impact on crime distribution [25]. The crime pattern investigations try to reconstruct the logic according to which the patterns of crime develop, organise and branch out within an urban agglomerate, within a social fabric. This is done to understand the spatial logic that guides the distribution of crimes - considered by typology in order to avoid erroneous evaluations [26] - and subsequently to elaborate specific intervention strategies. From a methodological point of view, crime patterns investigation is based on crime mapping. Digital technology progress had a decisive impact on this line: it has considerably increased the possibilities of calculation (data collection, spreadsheets, statistical elaborations…) and opened up new scenarios, still today with unpredictable and intriguing possible developments. Leaving aside the obvious contribution of ICT in the field of data analysis, the scope is here to analyse the contribution provided in the field of representation, spatialisation and prediction. In this development, a decisive step was the diffusion of Geographic Information System (GIS) software, which took place since the '90s and allowed the realisation of visual representations of spatial and temporal crime occurrences distribution [24].

On this basis, with this new digital support, the so-called crime hotspot mapping has developed and has quickly become a widely employed tool for crime prevention and policing resources [27]. In particular, crime mapping has proved to be a fundamental tool in two fields. From the theoretical point of view, it allows evaluating, discussing and testing the assumptions and the logic of crime theories. From a practical point of view instead, once it has been assumed that crime is not uniformly distributed [28], it has proved to be an embryonic predictive tool useful for understanding dynamics, situations and environmental recurrences to be addressed in urban planning. Over time, several hotspot mapping techniques have been developed, although the most widespread and least critical is *Kernel Density Estimation* (KDE), although not being able to consider the crime occurrences timing [28].

However, further technological and IT advancement has allowed – moving from the embryonic predictive character of crime hotspot mapping – more refined tools, which have gradually led to models that take into account the concept of risk. In particular,

since the 2000s, predictive tools and risk assessment tools have been developed, often tested in cooperation with government agencies and in many cases being adopted by police forces offices. Examples of these tools are *Promap*, proposed in 2004 [29], which introduced the time variable in predicting crime; *Predpol* (originally called self-exciting point process (SEPP)), introduced by Mohler et al. [30], which is based on the concept of risk and it is able to estimate the possibility that a crime occurrence will occur in spatial-temporal terms; the *Risk Terrain Modeling*, introduced by Caplan et al. [31], which is a forecasting technique – based on the overlapping of multiple risk factors – aimed at determining the micro places where future crime will occur; the *Vulnerable Localities Index and Harm Mapping*, structured on the risk, vulnerability and harm variables; the *Security Rating Index* by Shach-Pinsly [32] that proposes a method to elaborate risk maps without the need for data about past crime occurrences. Finally, *Agent-Based Models* (ABM) represent a very intriguing scenario. Those models have developed considerably in the last 10 years, and they consist of models of interacting agents able to emulate human behaviour taking individual decisions based on a few initial hypotheses [33]. This permits the realisation of tests that would be unethical in society, evaluating and forecasting situational behaviour and group behaviour dynamics [33].

From this quick summary two fundamental aspects emerge. First, it can be seen how technological evolution allowed instruments originally employed exclusively in the theoretical field to evolve into new applications useful for operative tasks, passing from the simple geographical representation of criminal distribution instruments to predictive ones, also able to provide support to police forces and institutional decision-makers. This development has in fact provided tools that, whether combined with criminological and urban planning knowledge, have made possible the investigation of the future rather than the analysis of the past, broadening the focus of environmental criminology to crime prevention rather than post-event investigation or repression. This development, moreover, considering its last and further steps, may become increasingly decisive in the daily live fight against crime in a safe-smart interconnected cities logic. Secondly, an aspect strictly connected to the first one: it clearly emerges what impact digital technology and computer progress may have in the future on the security issue. Just considering the reconstruction of the crime pattern investigations, examined here, it emerges how, in just over 30 years of research, very powerful and unpredictable instruments have been elaborated. On this basis, it is expectable that IT and ICT progress will give crime science and urban crime prevention the necessary support in creating advanced tools for promoting safer cities. In this sense, the joint development of new technologies with tools for reading urban space and environment dynamics, such as Isovist analysis and Space Syntax, represent a fascinating aspect, especially concerning the analysis of human behaviour in urban contexts, the distribution of people flows in the city and the impact of surveillance, as described below (par. 3.4).

Moreover, technological development has also strongly influenced the conception of the city. In fact, over time, increasingly sophisticated systems capable of interconnecting the city have been developed. This with the aim of making them smarter, more connected and well-organised in response to its ever-increasing size and complexity [34]. The concept of smart city has developed and it is now widely used, promoted by many urban programs and incorporated into many government strategies [35]. It has not achieved a

final unique definition, being discussed by many fields. However, taking up the various formulations made over time [36], it emerges its aspiration in promoting well-being, inclusion and citizens development. This is achieved through ICT-based solutions aimed at optimising existing networks (real and virtual), innovation and development policies that involve the macro-themes of economy, environment, governance, living, mobility and people [37].

The concept of safe city is associated with the concept of smart city. It develops ICT and IoT systems in order to increase real and perceived security, by recognising the negative impact of crime and lack of security on people's wellbeing. These concepts usually define smart safe cities. However, as Lacinák and Ristvej [38] point out, the field of security is still underestimated and marginal in most smart city studies. This paper intends to fuel interest in investigations on this topic, focusing in particular on the role of surveillance and the possible developments guaranteed by AI.

3.3 The Role of Surveillance in Promoting Urban Security

The fundamental role of surveillance in the promotion of security clearly emerges. Jacobs [17], Angel [18] and Newman [12] first pointed out the importance of this aspect in designing the urban environment. Subsequently, crime theories examined in detail the role of surveillance - whether formal (police patrol, CCTV, sensor systems) or informal (referring to the eyes on the street of the actors living in the city) - highlighting the deterrent power against criminals in a benefit-cost analysis and rational choice logic [13, 39, 40]. Today, surveillance is still a primary tool in the development of security policies, which is also confirmed in the recent guidelines for CPTED (BS ISO 22341:2021). For this reason, ICT science is constantly looking for new systems and technological solutions in this sector, already widely used by governments around the world to increase security [41]. In particular, many systems designed and implemented in cities as part of smart and safe city programs include surveillance as a fundamental tool to tackle crime and, according to much research, even insecurity. The relationship between surveillance and perception of safety is indeed a focal aspect: the debate lies between the ability to reduce the fear of crime through the increasing certainty of punishment, the psychological impact of a sort of 'ipercontrolling society' and the issue of privacy and transparency of data use. However, this complex discussion is left out here and deferred to further studies. Instead, this paper provides a general overview, without claim of completeness, of the AI surveillance techniques, the related enabling technologies and a general surveillance device categories list.

Technological development and ICT research are leading to a considerable growth in artificial intelligence (AI), which is being used increasingly in the creation of smart and safe cities. One of the aspects in which it is being increasingly used is surveillance. In fact, it turns out that at least 75 out of 176 countries in the world are using AI technologies for surveillance purposes (Fig. 1) [41].

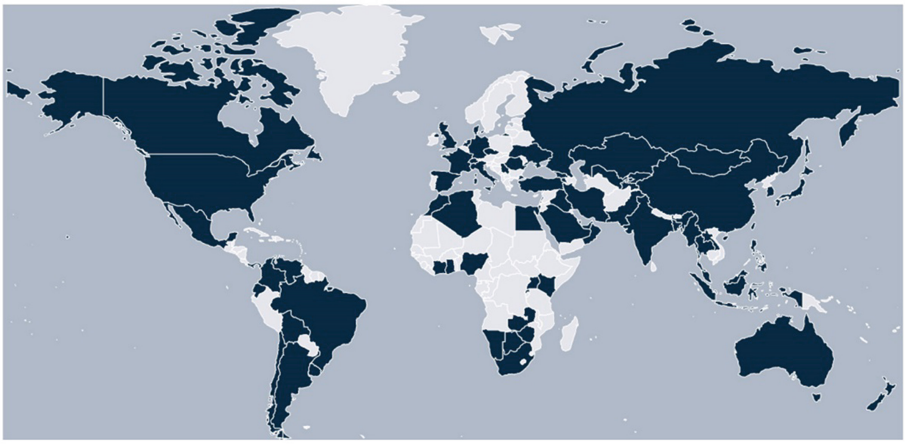

Fig. 1. Countries using AI technologies for surveillance aims. Adapted from Feldstein 2019.

From a technological point of view, three key AI surveillance techniques can be described, referring to the classification of Feldstein [41] where the AI Global Surveillance (AIGS) index is introduced. First, the *smart/safe cities*, i.e. the use of sensors that transmit real-time data for, among other things, public safety, which may include facial recognition cameras or police body cameras connected to a central station to prevent crime and respond to emergencies. Second, the *facial recognition systems*, namely the use of biometric technology to recognize individuals and match them with existing databases or evaluate demographic trends or detect feelings via facial recognition (see [42]). Third, the *smart policing*, that is a data-driven analytic technology usually incorporating predicting systems and algorithmic analysis to improve police response. A schematic visualization of the AI surveillance techniques adopted by different countries around the globe is proposed in Fig. 2. Then, the main enabling technologies responsible for realising the aforementioned techniques are the Automated Border Control (ABC) Systems, Cloud Computing and Internet of Things (IoT).

The types of surveillance devices are numerous and constantly evolving. Listing the main ones that come to the authors' mind, there are: surveillance cameras, aerial surveillance or satellite imagery, radio frequency identification and geolocation devices (Radio Frequency Identification tagging, GPS, mobile phones). Moreover, computer surveillance, telephone tracing, social network analysis, biometric surveillance, data mining and profiling. However, the authors suggest the realization of a periodically updated systematic review of all technologies in the field of security - whether instruments, software and systems in general – to provide an exhaustive and comprehensive view of all the existing tools, filling in this way an existing gap.

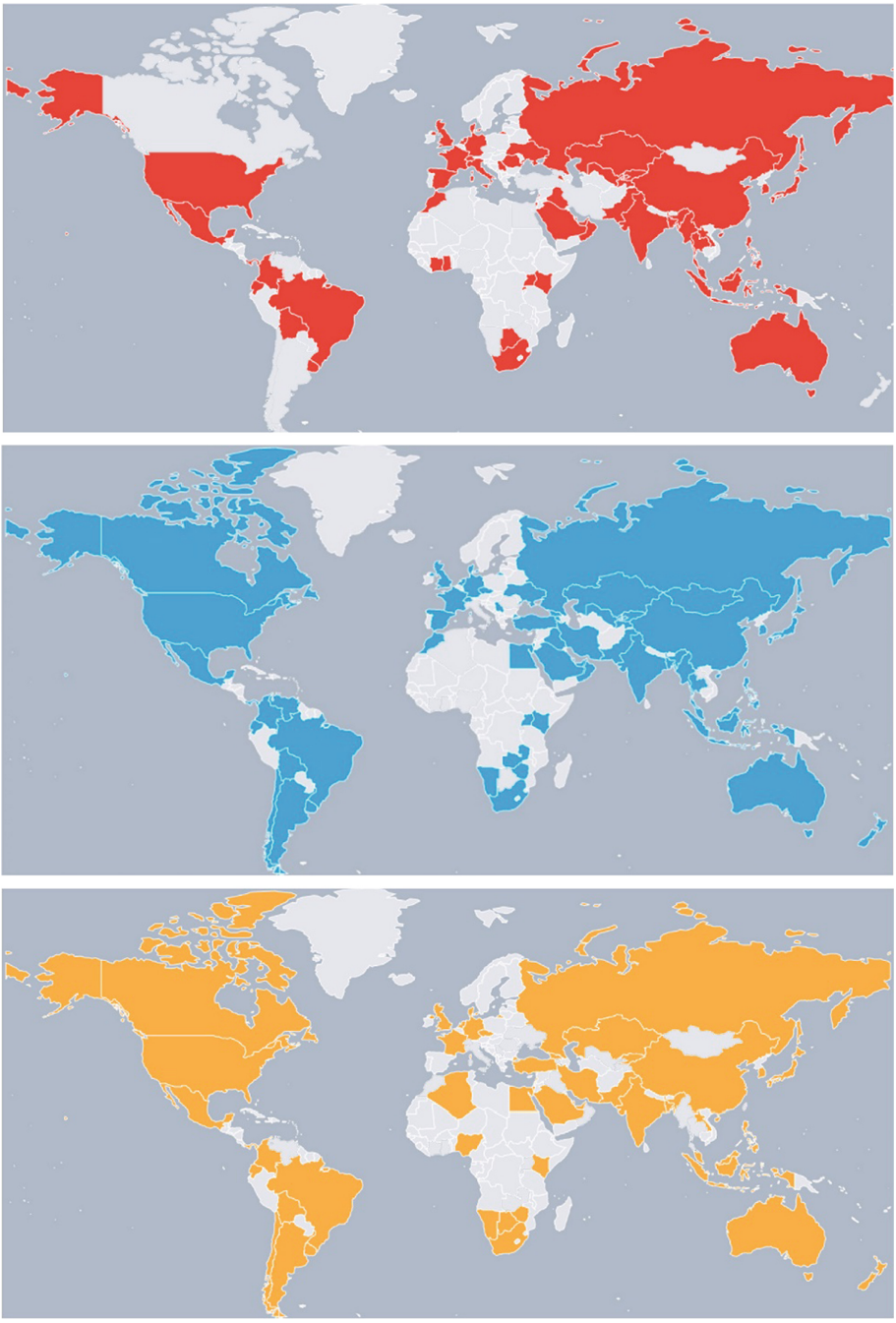

Fig. 2. AI surveillance techniques adopted around the globe: smart/safe cities (a), facial recognition systems (b), smart policing (c). Adapted from Feldstein 2019.

3.4 Exploring the Roots of Surveillance: Isovist, Viewfield and Visibility Graph Analysis

What is surveillance from a conceptual point of view? Although the surveillance construct can refer to a very wide range of meanings, we would like to focus here on visual surveillance. It has always been the leitmotif associated with security and has found a utopian but emblematic declination in Jeremy Bentham's panopticon [43], then becoming central in theoretical crime prevention studies from Jacobs onwards. Visual surveillance in urban contexts refers to the viewfields that the urban configuration allows human beings and any electronic devices placed on the territory, thus creating more or less controlled areas affecting the probability of crime to occur [39]. In fact, just as in the graph theory (for example, referring to the emblematic Königsberg bridge problem) the possibility to find a specific path depends on the inner properties of the graph, and in the configurational theory the properties of an environment depend on the urban form, in the same way, visibility is a characteristic mainly dependent on the spatial configuration and capable of affecting people behaviour. Therefore, urban-visibility characteristics should be taken into account in urban planning and environmental design. It should be stressed that only the manifest presence of people and electronic surveillance devices have a direct effect on crime prevention, being otherwise, through their hidden presence, useful only for possible punitive and repressive purposes. Tandy [44] appears to be the first to have used the term 'isovist', when in parallel the terms 'viewshed' and 'intervisibility' were spreading respectively in the field of landscape architecture [45, 46] and in computer topographic modelling [11]. An isovist is defined as "the set of all points visible from a given vantage point in space and with respect to an environment" [47]. Benedikt [47] contextually introduced a set of measures of isovist properties able to allow quantitative analysis of spatial environments, and he suggested that the way we experience the space is connected to the interplay of isovists. Gibson [48] in particular introduced the concept of perceptual quality of the isovist field. Then Turner et al. [11] integrated the isovist concepts with the graph-based representations – namely the Space Syntax theory and its set of techniques – to interpret networks of social behaviour, obtaining in this way the visibility graph of the environment, which is defined as the "graph of mutually visible locations" [11]. This was done to overcome the hitherto existing limitations, i.e. the absence of studies of relations between viewsheds. In this vein the Visibility Graph Analysis (VGA) develop, representing a technique for analysing the intervisibility connections of the urban grid [11, 49], which evolved over the years through the definition of specific environment-reading measures (for a summary see [50]). Much research, both from the urban planning and criminological fields, highlight the primary role of visibility and surveillance. However, as Turner himself pointed out [51], it is fundamental to overcome the assessment of visibility in vacuo and in 'stationary terms' by referring to fixed positions. For example, Lee and Stucky [52] already faced the isovist variation along a pathway, discussing the path's visual characteristics in terms of pleasantness. Penn et al. [53], Batty and Jiang [54] and Conroy [55] investigate virtual reality (VR) environments in terms of visual paths. In this regard, the study of Turner [51] is noteworthy, from which important aspects emerge. The first is that visual integration is not related to pedestrian movement, while the agents in its Agent-Based Model are, although transition probability is directional. The second is the acknowledged importance of the

agents as samplers of the visual configuration, and the suggestion to go back to simpler models of the environment in determining the agent logic of movement: axial lines [56] or sparse visibility graphs between topological nodes [57]. More specifically, Turner himself proposed the use of ABM to correlate human 'individual' movement paths and configurational properties, which is, as argued in this paper, a further development to be achieved. Recently, Benedikt and Mcelhinney [58] have emphasised the importance of studying the pathways within the environment, for example to carry out analysis in terms of privacy or for the CCTV and security guards positioning. By analysing these aspects, they focus on the importance of the concept of occlusive surfaces, which are permeable boundaries "that lie between what can and what cannot be seen and yet through/across which movement is possible" [58]. These surfaces obstruct the view of something new, and only by getting past them it's possible to depart old things in favour of new ones. The focal aspect is that as humans we continuously relate with isovists and we make decisions based on isovists even without realising it: where we sit at a table, where we wait for a friend, what route we choose when taking a walk. We reason by 'good views'. Similarly, a criminal looking for the right opportunity to commit a crime [59, 60] will carefully assess the level of surveillance of places [13, 39, 40]. This is why the study of isovists and the development of surveillance maps as risk indicators can be decisive. Indeed, as Benedikt and Mcelhinney [58] point out, isovists have a great advantage in analytical terms in comparison with social studies, namely their being objective entities in shape and size. However, as Turner suggests [51], from the postpositivist point of view the people's background could impact the visual and space perception, thus being an aspect to be further addressed. Recently, the ISOVIST programme was introduced by Benedikt and Mcelhinney [58], as proof of the growing interest in investigating visibility aspects.

3.5 A Digital Surveillance-City Model: A DSS Integrating Isovist and Space Syntax Logic

We now propose a possible development – here presented in its conceptual idea, which will be the subject of future in-depth studies – aimed at studying the urban environment from a surveillance perspective, aimed primarily at urban security but also extendable to other types of urban analysis. Therefore, considering: the studies carried out over the years on the subject of isovist, Visual Graph Analysis (VGA), and in particular on the aforementioned works of Benedikt and Turner; the whole configurational theory and in particular Space Syntax with its ability to interpret the human behaviour in space (for more details see [49, 61]); and, finally, considering the importance of surveillance in environmental criminology, the study was then developed.

If we consider an environment and a person located there, it is possible to define and represent (e.g. through the ISOVIST application illustrated by Benedikt and McElhinney [58]) the isovist of that individual (Fig. 3a). It is also possible, in general, to study the viewfields of an agent moving according to a certain path in space, and therefore how the isovists vary in time. In particular, it is possible to define the agent 'visual field properties' on the basis of the agent inner characteristics or the type of analysis to be carried out. It could be set, for example, the width of the visual field, hypothesising the behaviour of the agent (more or less interested in visually exploring the surrounding

environment), depending on the relationship that links it with the environment (Fig. 3b). In fact, Van Nes and Yamu [49] point out how in the urban context, for example, a local, a tourist or an average person have different behave, thus affecting the path and, as a consequence, the isovists over time. In addition, considerations could be made on the part of the environment that although not being part of the visual field, could be considered under the 'partial control' of the agent [58], thus evaluating 'grey zones' representations. Similarly, it could be considered the reduction of the agent's visual field extension by making appropriate considerations about the human capacity to visualise things at a certain distance, in relation to a specific type of crime, for example. Ultimately, it will be possible to represent, for each instant, the isovists of the agent living the environment (Fig. 3c), with the designed 'visual field properties'.

According to similar reasoning, the isovists of digital surveillance devices can be represented (Fig. 4a), and they could easily be integrated with the previous representation (Fig. 4b). Moreover, by integrating in a single representation the isovists of digital surveillance devices (e.g. CCTV) and the isovists of people experiencing that space, it is possible to represent the hypothetical surveillance map of that environment for a given instant t (Fig. 4c).

This is technically feasible with today's existing tools, and it would allow – if data on the exact position of all the people at different times and the 'visual field properties' of each of them were available – to represent the dynamic surveillance map of that environment. This could permit the identification of the more fragile areas in terms of visibility and surveillance, and it could guide interventions aimed at security improvement – by taking into consideration the crime theories logic – at different scales and in different areas: mobility planning, requalification and rehabilitation, urban planning and urban design, lighting, CCTV and police patrols disposal optimization. However, as already mentioned, here the sensitive issue of privacy strongly emerges. How to overcome this problem? This paper tries to overcome the problem by proposing a solution that minimize the data needed in input, still creating a useful decision support tool.

Then, in further studies, the limits and variants that can ensure the optimal development of the model will be discussed, considering both the goal of a safer community and the personal right to privacy, also considering different existing regulations thorough the world [41].

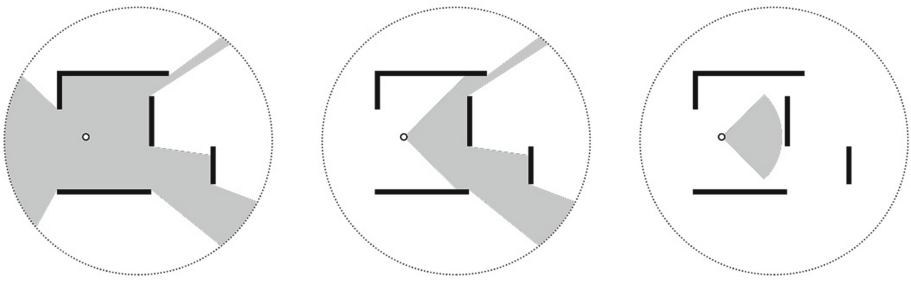

Fig. 3. Scheme of one-agent isovist with 360° and infinite extension (a), 90° and infinite extension (b), 90° and finite extension (c) visual fields within the environment.

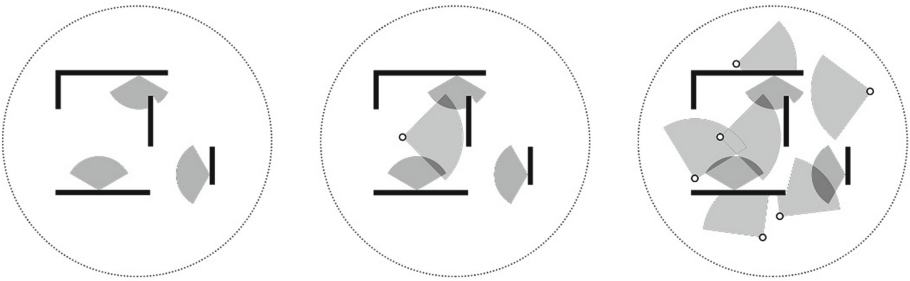

Fig. 4. Scheme of CCTV viewfields (a), CCTV viewfields and one-agent isovist with 90° and finite extension visual field (b), CCTV viewfields and random-positioned agents isovists with 90° and finite extension visual field (c) within the environment. The scheme 4c thus represents a momentary hypothetical surveillance map at a given instant t.

Therefore, considering the general impossibility in tracking the precise agents movement and their visual fields while experiencing the space (situations possibly allowed in maximum security areas requiring anti-terrorist measures, such as airports), the real surveillance map of a given area is not feasible. Here, however, the space syntax comes into play with its ability to interpret the human attitude in terms of flow and movement. In fact, referring to Hillier's theories [62], it is possible to interpret the movement and the human behaviour within a space through the analysis of the space itself ("Space is the machine" [62]), and therefore, as far as we are concerned, it is possible to establish which are the flows in a space through the configurational analysis. In particular, through the axial analysis and the integration, connectivity and choice measures it is possible to assess which routes are most travelled. Moreover, according to the interpretations made by Summers and Johnson [63], it is possible to hypothesise different attitudes – and therefore isovists according to van Nes and Yamu [49] – of the users of the areas. In particular Summers and Johnson [63] hypothesise that the connectivity measure, being a local indicator of accessibility, may represent the movement of locals, which have a higher sense of belonging to their living areas [12, 17]. On the contrary, following this interpretation, integration and choice measures could represent average person patterns. So, we could conduct an axial analysis of the environment and consider, for example, the integration measure (Fig. 5a). At this point we could decide to spatialize this measure, using for example the methodology illustrated by Berhie Haq [64]. Anyway, following the axial analysis, it's possible to create a map representing a hypothetical probable – as supported by the space syntax theory measures (in this case integration) – position of people in the environment and their field of view at a given instant t (Fig. 5b), that is what we can call hypothetical probable surveillance map. With this step then, that is the integration of flows measures with isovists, we proceed towards the integration of perceptive and behavioural aspects, key-issue in urban environment analysis and space syntax investigations.

However, this model still presents two substantial criticalities, leaving aside the needed further investigations aimed at correlating Space Syntax measures and agent visual field properties as well as a more detailed description of the methodology that goes beyond the schematic conceptualisation. The first concerns the distribution of people

in the space - proportional to the Space Syntax measures but randomly positioned - and the orientation of the isovists, which are randomly decided. In fact, although the number of people could be decided proportionally to the Space Syntax measures and the visual fields properties can be modelled according to the type of investigation to be performed, the random positioning represents a weakness of this model. The second concerns the model's limitation in terms of time variable analysis. In fact, this model allows the representation of fixed instants t, while, as Turner [51] suggests, it is necessary to overcome the idea of a static, immobile visualisation in favour of a dynamic one, since it is precisely the variation of isovists over time that defines, more or less consciously, the path the agents undertake while experiencing the space and, from an external perspective, that defines more or less surveilled areas.

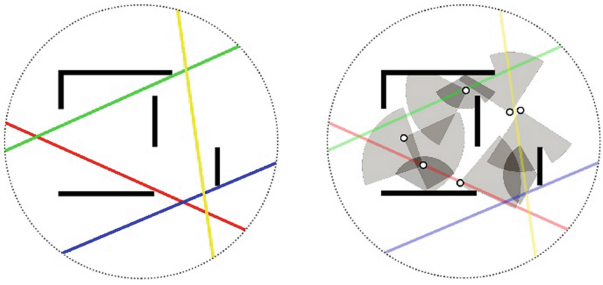

Fig. 5. Scheme of an Axial Analysis (integration) of the environment (a). Scheme of CCTV viewfields and Axial-Integration-related agents isovists with 90° and finite extension visual fields within the environment (b). The scheme 5b thus represents a hypothetical probable surveillance map at a given instant t.

In order to address these weaknesses, which can be summarised as positioning-orientation randomness and isovists stationarity, ICT can be decisive. In fact, referring to what has been said in the previous paragraphs and referring to Turner's studies [51], ABMs could be the ideal tool to integrate the concepts of isovist and configurational analysis, at the same time overcoming the aforementioned criticalities. This integration could push towards the realisation of reliable predictive tools in terms of surveillance. In fact, considering the characteristics of the ABMs, it would be possible to insert additional information to increase the adherence of the model to reality, thus obtaining realistic simulations of surveillance in public spaces. Many types of information could be included: the social behaviour of agents, the land use, the type of activities within the environment and their working hours, the time of day (e.g. night and day could produce very different situations in terms of surveillance). Moreover, this tool could be used not only for crime prevention but also to test in advance the effects on surveillance of hypothetical urban transformations, thus being able to evaluate different alternatives, just as space syntax is already being used. For example, in organising a city event that temporarily modifies the road network and provides for the installation of temporary structures, it would be possible to evaluate different options from multiple perspectives: the impact from the visual point of view, the areas that would be most affected by weak surveillance, the dynamics that could be generated in terms of flows, in addition to all the

evaluations that the space syntax already allows. And again, as a decision-support tool for urban planners, it could allow assessments of the establishment of new activities, their location and the visual impact they might have, as well as acting as a decision-making tool for private companies to evaluate the optimal location and arrangement of their activities. Furthermore, and this aspect is truly crucial, this model would be, at least in its basic formulation, independent of the availability of sensitive and aggregated input data that could undermine its effective use, particularly in certain contexts [41].

4 Concluding Remarks

This paper presented the very preliminary results of the elaboration of a digital city-surveillance model obtained from the integration of isovist and space syntax concepts, with a further development consisting of the realisation of a surveillance-oriented Agent-Based model. The potentialities of the model have emerged both from the theoretical and operative perspectives. It can represent a tool to fuel the theoretical debates on environmental criminology and, at the same time, it can be employed as urban planning DSS considering its predictive nature. In particular, the strength of this model consists of three aspects: its possibility of realising surveillance maps that include the temporal component; its ability in correlating perceptive and behavioural aspects; its adaptability in terms of sensitive input data, which permits the model to fit different contexts overcoming the privacy issue still maintaining its effectiveness.

As discussed in the core of the paper, further investigations are required to develop this model: first, it's necessary to deeply explore the Space Syntax measures and refine their interpretations in terms of inhabitants 'characterisation', behaviour, movement – which directly affect the isovist 'dynamics' – and consequently visual field properties. Second, the validity of the methodology has to be confirmed with the elaboration of case studies and through the critical comparison with alternative methodological steps, which can include for example VGA. Third, a technical investigation on how to integrate movement and visual components into an ABM is required.

Moreover, additional intriguing research gaps have been identified; namely the investigation, as Turner [51] suggests, of how different cultures, memories and experiences impact space perception, following the postpositivist logic, as well as the psycho-physiological impact of the environment on the people who are experiencing it. These aspects, if properly addressed, could improve the ABM model and make it increasingly refined. Additionally, taking Turner's [51] cue not to limit studies of isovists in vacuum, the possibility to investigate the effects of people concentration on isovists and human perception, as well as the threshold level whereby the presence of additional "eyes on the streets" produces negative effects emerges. Furthermore, an updated systematic review of all the technological security-aimed tools, software, systems and models, as well as an extensive review of all the ABM models implemented in a surveillance-visibility logic or anyway adaptable to it are interesting research insights.

More in general, this paper had the aim to foster the collaboration between criminologists, urban planners and computer scientists and to feed the interest in visibility and surveillance as fundamental aspects in the elaboration of urban planning strategies, both from the urban security and environmental management perspectives.

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