

## Original Research Article

## Effective Spatial Syntax Indicators for Crime Hotspot Identification

(The Case of Hamedan Bazaar)\*

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**Abstract**

**Problem statement:** Among the most significant challenges of the majority of historic bazaars is that there are social issues that jeopardize security. The research case of this study is within Hamadan Bazaar, which is subject to the aforementioned social problems. The primary research question is whether Space Syntax software can be used to analyze crime locations that have been caused by physical and non-physical factors. One particular gap in the literature for this research is that no definite explanation of the ability of the software to detect crime locations that have been caused by non-physical factors has been created.

**Research objectives:** The primary objective of this research is to analyze the efficacy of the Space Syntax method and its key indicators in identifying the crime locations caused by physical and non-physical factors. Further, it investigates whether the software can identify crime locations caused by non-physical factors. Moreover, the research suggests both physical and non-physical interventions towards enhanced security and reduced crime in the study area.

**Research Method:** The study employed a cognitive map to determine and categorize the places and nature of crime within the study area. The study area was then analyzed with the use of UCL Depth Map software in order to examine its spatial syntax and determine the influence of physical aspects in the creation of crime hotspots.

**Conclusion:** Through comparison of the derived quantitative and qualitative data, the study confirmed and categorized the physical and non-physical determinants of crime hotspots. The study evaluated the effectiveness of the Space Syntax approach and its most significant criteria in determining crime hotspots. The study concluded that the software cannot identify crime locations resulting from the non-physical determinants.

**Keywords:** *Space Syntax, Crime Prevention, Cognitive Map, Hamedan Bazaar.*

**Introduction and Problem Statement**

Security, as one of the fundamental human needs, has been a priority concern for urban planners and policymakers for centuries, and extensive efforts have been made to ensure its provision. As the lower physiological needs become increasingly satisfied in modern societies, the relative importance and

urgency of security have become increasingly poignant (Maslow, 1943, 377). In the traditional market of Hamadan—the study focus of this research—security deficiencies can be witnessed, with crime appearing as a key urban problem. Spatial arrangement and environmental design play a crucial role in the patterns of crime (Greene

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& Greene, 2003; Hillier & Sahbaz, 2008; Nubani & Wineman, 2008; Tavares Monteiro, 2012; Akkelies, Van Nes, & López, 2010; Zaki et al., 2008). Potential offenders notice suitable targets when engaging in their regular activities, as suggested by Cohen and Felson (1979). Felson (2006) continues to say that offenders initially attempt to evade surveillance and then target locations that are characterized by neglect and absence of supervision (Felson et al., 2021; Moir et al., 2019; Robinson, 2021).

The occurrence of some crimes is closely related to specific environmental characteristics. By analyzing environmental factors and introducing targeted interventions, the opportunities for crime can be reduced and prevention enhanced. The Crime Prevention Through Environmental Design (CPTED) strategy emphasizes control and reduction measures of crime hotspots, and environmental criminology highlights the spatial context's role in shaping criminal behavior (Brantingham & Brantingham, 1993; Johnson et al., 2007; Rey et al., 2012; Ye & Wu, 2011). Interestingly, many of the early CPTED principles were organically incorporated into historic urban fabrics, without any intentional design intention. However, the invasion of automobiles and the resulting street widening disrupted these cohesive spatial patterns, creating neighborhoods with diminishing control and surveillance. In the historic core of Hamadan, street widening, modern reconstructions, and the physical boundaries established around the Hegmataneh archaeological complex have caused widespread structural transformations. These transformations have introduced new security issues into the traditional bazaar. The formation of crime hotspots here can be attributed to physical and non-physical determinants. Accordingly, the primary objective of this study is to assess the viability and applicability of the Space Syntax technique and its associated indicators in identifying crime hotspots influenced by both categories of factors.

## Research Questions

From the above discourse, this study seeks to address the following research questions:

1. To what extent can the Space Syntax technique identify crime hotspots that are associated with physical spatial features?
2. To what extent can the Space Syntax technique identify crime hotspots that are defined by non-physical factors?
3. Which Space Syntax measures are most effective at identifying and explaining the spatial distribution of crime hotspots?
4. Following the identification of crime hotspots using the Space Syntax technique, what are the specific measures that can be implemented to curb crime in those areas?
5. What are the underlying reasons for the formation of crime hotspots in comparable historic urban fabrics worldwide?

## Literature Review

Crime site spatial characteristics have been widely studied using the space syntax analysis and its combination with the theory of Crime Prevention Through Environmental Design (CPTED). Of them, Reis et al. (2003) specifically used cognitive mapping to obtain qualitative data, thereby complementing the quantitative in space syntax and CPTED methodologies. Together, these studies contribute much to our understanding of how spatial configuration influences the prevalence and perceived safety of crime. Some of the findings highlighted are listed below. Reis et al. conducted a study to assess the spatial configuration features and perceived safety by residents in two poor neighborhoods. Based on their study, sites that possess syntactic features such as segregation and greater depth and are associated with low social control are more susceptible to crime (Reis et al., 2003, 1). Similarly, Hillier, in his groundbreaking paper "Can Streets Be Made Safe?", discusses how spatial layout impacts criminal occurrence. He argues that the hierarchical organization of current street networks, as opposed to the networked structure of traditional conventional designs, facilitates various modes of criminal activity. Hillier proposes several design principles

to ensure urban safety, including increasing building connectivity, decreasing secondary points of access, aligning domestic frontages with public space, and increasing direct visibility (Hillier, 2004, 31). Hillier and Sahbaz contend in a more recent London study that making criminal offenses more difficult to commit is one of the primary objectives of urban design. They demonstrate that various crimes are connected to certain spatial configurations, and therefore, crime prevention is inevitably multifaceted. Nevertheless, they conclude that increasing local movement potential—facilitating natural pedestrian flow—reduces crime occurrence (Hillier & Sahbaz, 2008, 2). Chang, in the paper “Social Crime or Spatial Crime?”, contrasts the relative significance of social, economic, and spatial considerations to the crime rate of theft in six urban areas. The findings are that areas that have greater pedestrian access and higher observation provide less susceptibility to crime (Chang, 2011, 26–27). Matijosaitiene synthesizes ideas of CPTED with syntactic space analysis, arguing that examination of the constructed environment can be a sound crime reduction strategy. Her research shows that in each of the case cities, car theft increases proportionately as syntactic depth increases (Matijosaitiene, 2016, 49). Similarly, Jiang and Huo apply space syntax to investigate crime prevention in public open community spaces. They identify several safety shortcomings, including bad street access, poor control at the entry-exit points, ill-defined boundaries, and no areas encouraging social interaction—all contributing towards feelings of insecurity (Jiang & Huo, 2020, 38). Kazvani and Saeed, in the article, examine the influence of urban permeability and impermeability on crime rates in terms of the fear of crime. The authors refer to two conflicting models under the umbrella of CPTED (Crime Prevention Through Environmental Design) and focus on the hypothesis that restricted entry leads to less natural surveillance. This, consequently, creates a place for illegal use by unauthorized individuals, thereby leading to increased fear of crime

(Kezuwani & Said, 2021, 70). Nubani and Wineman (2022) say in their article that planners, architects, and criminologists are still unable to predict criminals’ selection of crime sites. By examining the connectivity and integration of crime hot spots in the city of Ypsilanti, Michigan, USA, the researchers found that greater connectivity contributes to more neighborhood togetherness and neighborhood monitoring on the streets, thus less room for criminal activity (Nubani & Wineman, 2022, 12).

Ghorbanian, in a paper, investigates the effects of land-use spatial patterns on pedestrians’ perceptions of security in Manzariyeh and local market neighborhood spaces in Tabriz. The results of this study indicate that security in the city depends on internal axis and secondary node land-use arrangements, and these affect users’ traveling patterns (Ghorbanian, 2022, 57). Wen et al., in their article, do a quantitative analysis and propose crime prevention design countermeasures for aged residential districts according to Space Syntax theory and CPTED. Lastly, they conclude that it is true that improving spatial design and natural surveillance can really contribute to crime reduction and increased safety feelings in aged residential districts (Wen et al., 2024, 2087).

Similarly, Soleimani and Golabi examine the effect of urban impermeability on fear of crime, demonstrating that spatial organization—specifically features promoting natural surveillance and territorial reinforcement—played a central role in structuring residents’ perceptions of security (Soleimani & Golabi, 2024, 21). The following Table 1 categorizes the reviewed studies based on three perspectives: CPTED principles, influential Space Syntax parameters, and research methodologies.

This research differs from earlier studies on three principal points of innovation and distinction. The first difference of this study is that past studies primarily used methodologies such as interviews, observations, and police records in identifying crime hotspots. In this current study, however, the

Table 1. Analysis of Influential Space Syntax Parameters and Research Methodology in Previous Studies. Source: Authors.

| Authors  | Year of Publication | Research Methodology  | Influential Space Syntax Parameters  | CPTED Theories   |
|--|---------------------|---|--|--|
| Reis, Antonio.<br>Portella, A.<br>Bennett, J.<br>Lay, M. | 2003                | Space Syntax<br>CPTED<br>Cognitive Map<br>Questionnaire                                       | Integration<br>Control   | Jacobs' Theory: Eyes on the Street   |
| Bill Hillier   | 2004                | Space Syntax<br>CPTED<br>Police Crime Data  | Integration<br>Connectivity<br>Permeability<br>Intelligibility<br>Synergy  | Jacobs' Theory: Eyes on the Street   |
| Bill Hillier<br>Ozlem Sahbaz                             | 2008                | Space Syntax<br>CPTED<br>Police Crime Data<br>Local Taxation Data<br>Census Data              | Integration  | Jacobs' Theory: Eyes on the Street   |
| Dongkuk Chang  | 2011                | Space Syntax<br>CPTED<br>Police Crime Data and<br>Field Observation                           | Integration<br>Intelligibility<br>Connectivity<br>Spatial Depth            | Jacobs' Theory: Eyes on the Street   |
| Irina Matijosaitiene                                     | 2016                | Space Syntax<br>CPTED<br>Police Crime Data and<br>Field Observation                           | Integration<br>Choice<br>Connectivity<br>Depth                             | Newman's Theory:<br>Defensible Space                                       |
| Tian Hao Jang<br>Jun Huo                                 | 2020                | Space Syntax<br>CPTED<br>Direct Field Observation<br>and Interviews                           | Integration<br>Intelligibility<br>Connectivity<br>Mean Depth<br>Visibility | Jacobs' Theory: Eyes on the Street<br>Newman's Theory:<br>Defensible Space |
| Noor Kamilah Kezuwani,<br>Shahrul Yani Said              | 2021                | Space Syntax<br>CPTED<br>Analysis of Data from<br>Other Studies                               | Integration<br>Choice<br>Connectivity<br>Depth<br>Intelligibility          | Jacobs' Theory: Eyes on the Street<br>Newman's Theory:<br>Defensible Space |
| Linda Nubani<br>Jean Wineman                             | 2022                | Space Syntax<br>CPTED<br>Police Crime Statistics<br>and Demographic Data,<br>and Spatial Data | Isovist<br>Integration<br>Connectivity                                     | Jacobs' Theory: Eyes on the Street<br>Newman's Theory:<br>Defensible Space |
| Mahshid Ghorbanian                                       | 2022                | Space Syntax<br>CPTED<br>Literature Review  | Integration<br>Connectivity  | Jacobs' Theory: Eyes on the Street   |
| Yu Wen<br>Hong Qi<br>Tao Long                            | 2024                | Space Syntax<br>CPTED<br>On-site Survey   | Integration<br>Connectivity<br>Depth                                       | Jacobs' Theory: Eyes on the Street<br>Newman's Theory:<br>Defensible Space |
| Meysam Soleimani<br>Maryam Golabi                        | 2024                | Space Syntax<br>CPTED<br>Interviews and<br>Observation  | Integration<br>Connectivity  | Jacobs' Theory: Eyes on the Street   |

application of police records could not be done due to security constraints and the police's definition of crime. Therefore, this study utilized cognitive mapping for data collection. The second difference lies in the case study, which is different from other studies. We are studying an old urban texture that has evolved over time. The third difference is that,

while most past research had assigned physical reasons to be the primary reasons for the existence of crime hotspots, the present research indicates that some places become hotspots of crime due to non-physical reasons. This finding criticizes and reveals a fault in Space Syntax theory and highlights the necessity of integrating social and managerial

CPTED variables with physical Space Syntax analysis. Aside from that, this study also confirms the findings of previous studies on efficient spatial syntax markers for identifying crime locations.

### Theoretical Framework

The three broad themes addressed by the literature review are environmental security, spatial arrangement, and cognitive mapping. All three concepts add value to the explanation of how physical space, human practice, and urban safety correlate.

#### • Environmental security

The modern discourse on environmental security arose partly as a response to criticisms of modernist models of urban planning. Crime Prevention Through Environmental Design (CPTED) is perhaps the most esteemed model developed to limit opportunities for crime within built environments. The relationship between the permeability of street networks and exposure to crime is a matter of ongoing debate. New Urbanists argue that permeability of space enhances natural surveillance—"eyes on the street"—and thereby results in safer cities (Rudlin & Falk, 1999). The foundation for CPTED was laid by the pioneering studies of Jacobs (1961), Jeffery (1969), and Newman (1972) (Cohen, 2014). Jacobs spoke of the authority of informal social control in terms of being "eyes on the street." Jeffery created the first official definition of CPTED in his book "Crime Prevention Through Environmental Design", and Newman proposed the theory of "Defensible Space: People and Design in the Violent City" (Newman, 1972). Collectively, these writings formed the basis of first-generation CPTED, which asserts that proper environmental design can be used to minimize crime opportunities in advance. Six primary principles of CPTED strategies often consist of Natural surveillance, Access control, Territorial reinforcement, Image and management/maintenance, Activity support, and site/target hardening (Mao et al., 2022). In the 1990s, Greg

Saville and Gerry Cleveland advanced the second-generation CPTED theory, which increased the consideration of social factors and emphasized the characteristics, cohesion, and collective benefits of the social level (Cozens & Love, 2015). CPTED strategies have since been implemented at different spatial scales—from the individual building to neighborhoods, and even national urban policy formulation (Armitage, 2018).

#### • Spatial configuration and space syntax

At the same time that CPTED was being developed, British researcher Bill Hillier advanced Space Syntax theory in the late 1970s (Bill et al., 2018). The theory of Space Syntax states that spatial configuration—i.e., the relational design of spaces—has a quantifiable effect on human behavior (Fang et al., 2021). Spatial analysis is utilized across diverse types of spaces, including indoor environments, urban areas, and broader geographical regions, with analyses conducted at various scales to address specific research questions (Liu, 2017). Space Syntax, according to Hillier (1996) and Hillier and Hanson (1984), analyzes the relationship between spatial configuration and urban social processes (Hillier, 1996; Hillier & Hanson, 1984). Space syntax theory strives to identify a cause-and-effect relationship between the physical morphology of architecture and human society (Bafna, 2003). Spatial configuration defines a set of relations between various parts, such as urban streets, which are linked in a superstructure. According to this, the characteristics of spatial configuration concern the topology of a complicated superstructure (Hillier, 1996, 1999; Hillier et al., 1987; Yamu, 2014). Though Space Syntax has been able to map spatial behavior, it has also been criticized for only a limited application of social variables, along with partial failure to replicate the complete richness of urban activity (Bahman Jafary et al., 2013). Yet, empirical studies confirm the practicability of Space Syntax measurements in crime distribution, fear, and perceived safety analysis (van Nes, 2021). Most

applications of this method have been carried out in small-scale environments, e.g., hospitals, schools, and parks (Zhang et al., 2022; El-Hadedy & El-Husseiny, 2022).

**• Cognitive mapping**

The theory of cognitive mapping was developed to explain how human beings mentally perceive and navigate their physical environment. A cognitive map is an internal, mental model that marks a person’s conceptualization of spatial relations and subjective conceptualization of environmental characteristics (Sidanin, 2007). According to Downs and Stea’s (1973) conceptualization, cognitive maps are not only spatial models but also Personal expression, memory, and meaning-making processes (Downs & Stea, 1973). For the current research, police records could not be used for identifying crime hotspots due to accessibility constraints and definitional variation in reporting crime. Cognitive mapping, therefore, served as a secondary qualitative data collection instrument. Identification of crime hotspots was made possible based on residents’ mental maps of space, yielding useful information on the spatial security patterns of the researched historical urban morphology. The

theoretical framework of the study is presented in Fig. 1.

**Research Methodology**

**• Study area for identifying crime hotspots**

The city of Hamedan has been a central commercial hub, with its socio-economic and spatial growth centered around its traditional marketplace. Before the central square and radial street pattern developed in the 1930s, Hamedan’s old urban structure consisted of a coherent and integrated spatial pattern that extended over much of the city’s built-up area (see Fig. 2a).

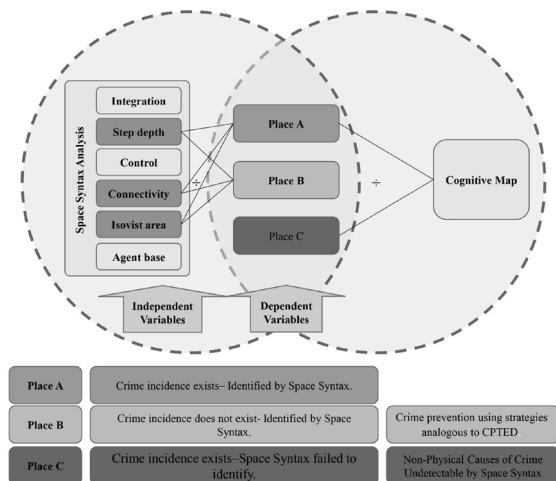


Fig. 1. presents the theoretical framework of the research. Source: Authors.

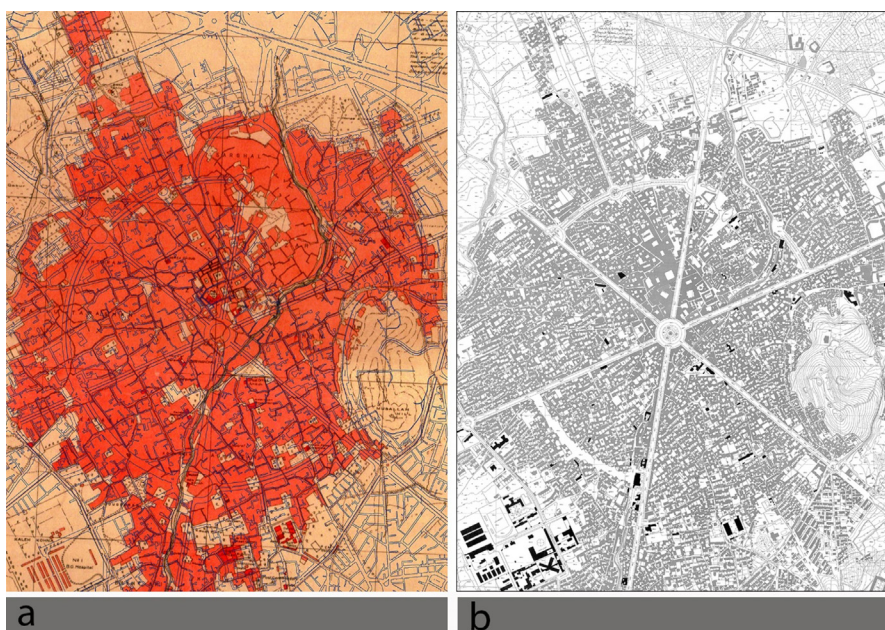


Fig. 2. A) - Overlap of the 1919 Map with the Current Map of Hamadan; B) - Map of Hamadan City After the Construction of the Central Square (Meydan-e Imam) and its Radial Streets (1968). Source: Authors.

The design of the new central square and six radially leading streets—by Karl Frisch and motivated by nineteenth-century European city planning philosophy—was a revolutionary period in the evolution of the city (see Fig. 2b). This intervention, nevertheless, was incompatible with the prevailing morphological and socio-spatial structure of customary Hamedan’s city texture. The resulting disturbance of the spatial continuity and coherence of the market produced a variety of urban issues, mainly in terms of security and the emergence of social abnormalities (see Fig. 3).

• **Research procedure**

This study is based on a mixed-methods approach that unites qualitative and quantitative methods of research in an attempt to offer depth of analysis and empirical robustness. At the first stage, a qualitative approach—cognitive mapping- was employed to identify the presence of crime hotspots (dependent variable) and the differentiation of crimes committed within the city center of Hamedan. The research area was mapped more spatially precisely on the basis of findings obtained for quantitative analysis. In the second phase, the spatial structure of the outlined study area was analyzed through the

implementation of Space Syntax methodology using the UCL DepthMap program, with emphasis given to its main spatial indices (independent variables). The third stage entailed comparative and statistical evaluation using Excel and SPSS software to check for correlations between the spatial indices (independent variables) and locations of crime occurrence (dependent variable). This helped in the determination of the most significant syntactic indicators related to the formation of crime hotspots. In the fourth step, the identified crime and anomaly locations were categorized and analyzed to evaluate the effectiveness of the space syntax strategy in identifying crime-potential sites. Finally, based on the analysis outcome, a set of design and planning interventions was proposed to reduce spatial vulnerability and enhance environmental security. The research process and methodological sequence are illustrated in Fig. 4.

Phase One: Identifying the Locations of Crime Through Cognitive Maps (Qualitative Approach)  
 The qualitative arm used cognitive mapping as the primary data collection instrument. The population of the study consisted of the board of trustees, guilds, and traders operating in the market area.



Fig. 3. Images of social anomalies within the study area. Source: Authors.

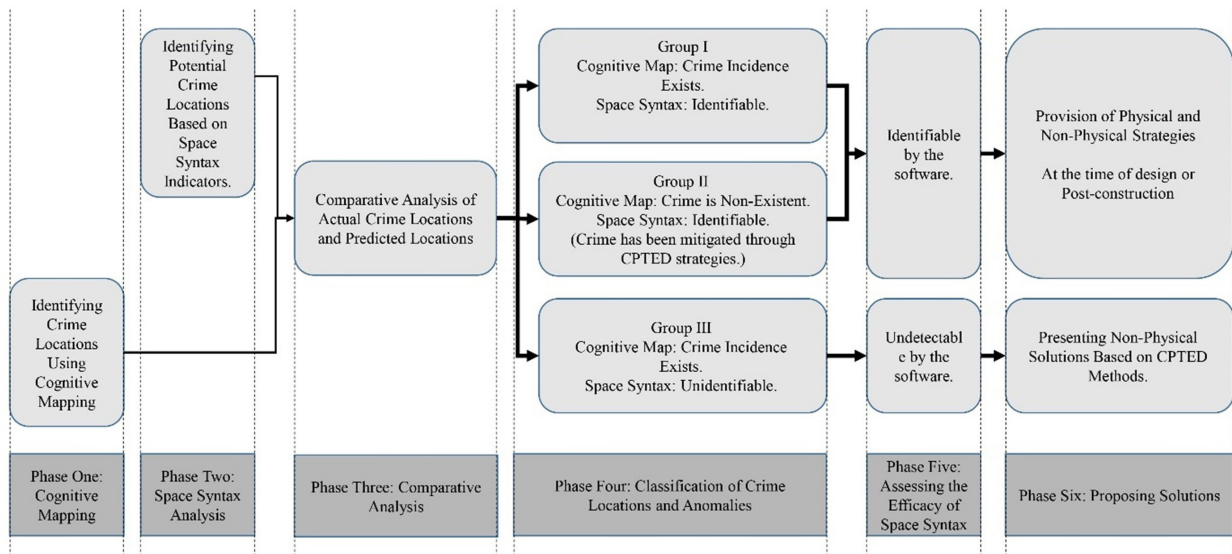


Fig. 4. Research Process Diagram. Source: Authors.

These were selected on the premise that most crimes occur off-peak, making shopkeepers the best eyewitnesses. Data gathering initially was conducted through gaining the participants’ trust and explaining the purpose of the research. In the first stage, 20 raw maps of the city’s outer ring were drawn, and participants were requested to trace the crime places and types using varying colors (see Fig. 5a). The results revealed a disproportionately high rate of crimes in one specific area (between Shohada Street and Ekbatan Street) compared to the rest. In the second phase, the map of the high-rate area was further annotated more completely (see Fig. 5b). Following compilation, the reported crimes and anomalies included drug consumption, drug dealing, public urination, prostitution sites, and sale of others’ property. Even though there is no perfect, universally applicable typology, crimes were typically grouped into violent crime, financial crime, and social anomaly/crime. Data analysis suggested that the majority of the incidents in the study area fell under social anomalies or financial crimes. The collection of cognitive maps commenced in September 2023 and was completed in January of the same year (see Fig. 5).

**- Phase two: space syntax analysis (quantitative method)**

The quantitative component was performed by employing the distinctive UCL DepthMap software in Space Syntax analysis. Space Syntax works to mathematically and graphically model spatial structures in a way that they may be analyzed scientifically and their effect comprehensible. The variables derived from this analysis are significant not for themselves but through their established correlations with established social properties, and thus, the technique becomes a valuable means of grasping socio-spatial formations (Rismanchian & Bell, 2010).

According to indices previously trialed in previous studies, the following Space Syntax parameters were used to examine the spatial structure of the study area: Integration, Step Depth, Control, Isovist Area, Connectivity, and Agent base. Usage and specific definitions of these indices are explained in Fig. 6.

**- Phase three: a comparative analysis of cognitive maps and space syntax maps**

This phase combined data obtained in Phases One and Two to compare the extent of concordance between the actual locations of crime as identified

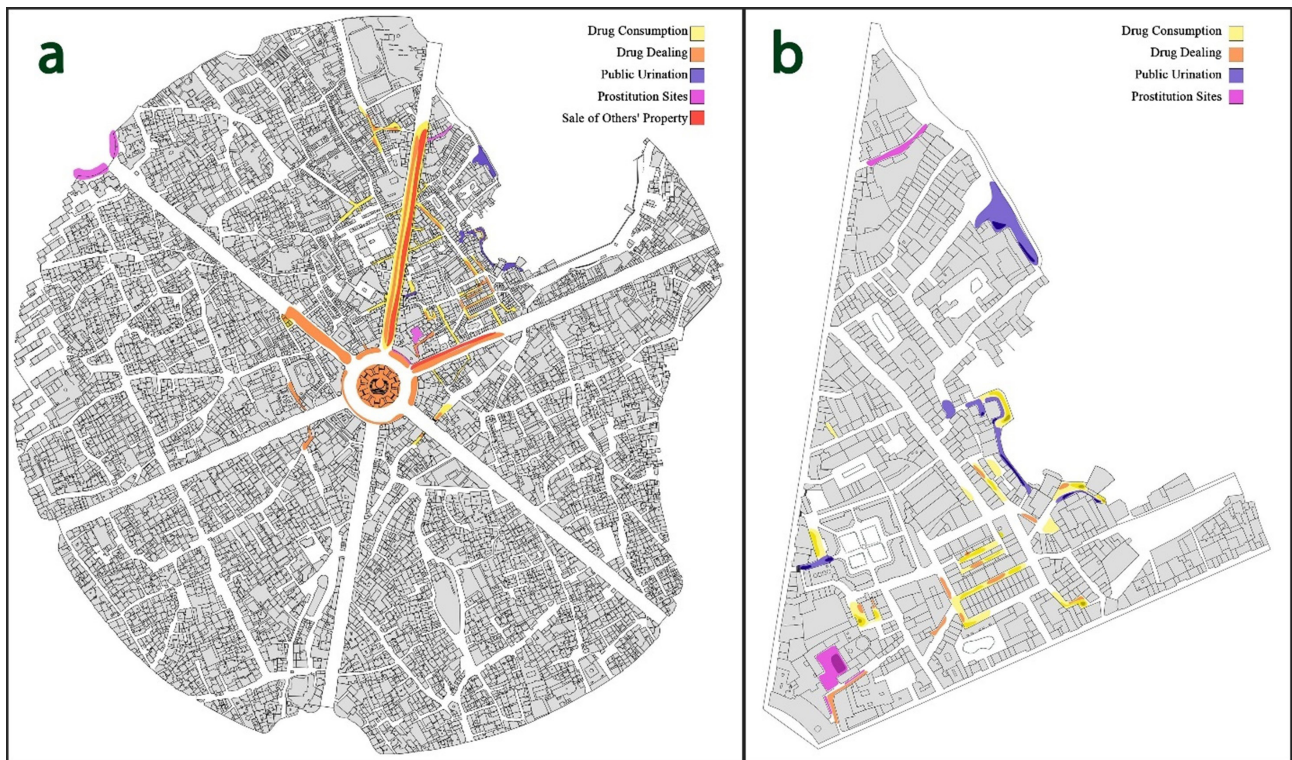


Fig. 5. A) Cognitive Map of the area within the six central sectors of the city; B) Cognitive Map of the area between Ekbatan and Shohada streets. Source: Authors.








| The data derived from the UCL DepthMap software                                     |            |   |              |   | high  low |  |
|---|------------|---|--------------|---|--|--|
|  | control    |  | Step depth   |  | Integration  |  |
|   | Avg        |   | Avg          |   | Avg  |  |
|   | 0.99       |   | 1.98         |   | 2.86   |  |
|   | Min        |   | Min          |   | Min  |  |
|   | 0.04       |   | 0            |   | 1.47   |  |
|   | Max        |   | Max          |   | Max  |  |
|   | 3.20       |   | 6            |   | 4.62   |  |
|  | Agent base |  | connectivity |  | Isovist area   |  |
|   | Avg        |   | Avg          |   | Avg  |  |
|   | 6.8        |   | 260.8        |   | 1047.1   |  |
|   | Min        |   | Min          |   | Min  |  |
|   | 1          |   | 5            |   | 30.08  |  |
|   | Max        |   | Max          |   | Max  |  |
|   | 58         |   | 961          |   | 3837.3   |  |

Fig. 6. Analyses of Integration, Step Depth, Control, Visual Area, Connectivity, and Base Factor. Source: Authors.

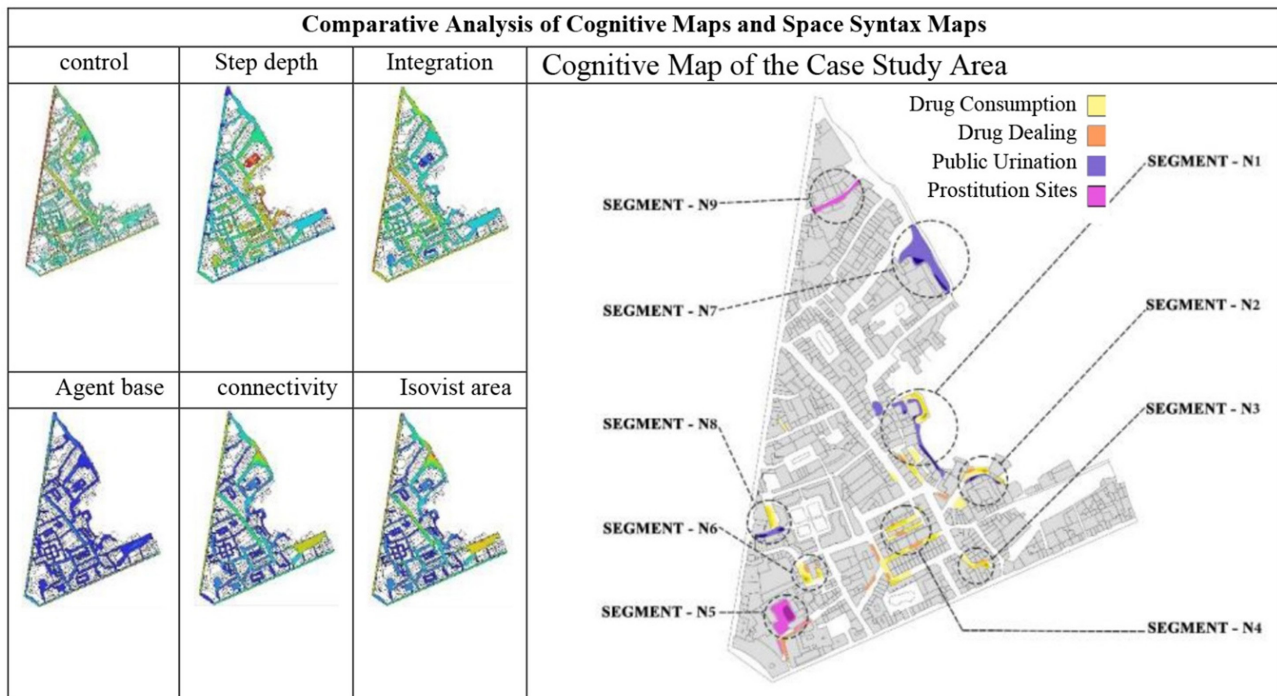


Fig. 7. Comparative Analysis of Cognitive Maps and Space Syntax Maps. Source: Authors.

from cognitive maps and those Space Syntax analysis had predicted. Preliminary results indicated a seeming correlation between Space Syntax indices and real locations of criminality (see Fig. 7). Aside from the general comparative analysis, correlation tests using non-parametric methods were also conducted to statistically examine each effect of Space Syntax indexes on the formation of hotspots. Statistical comparison was conducted using Excel and SPSS programs to determine the most predictive index for crime location identification.

Every crime hotspot indicated by cognitive mapping in the study area was identified as Segment N<sup>1</sup> to Segment N<sup>9</sup>. The ratio of occurrences of crimes (from the cognitive maps) in each hotspot to that of the corresponding numerical value of the associated Space Syntax indices at the points was found and examined, employing Spearman’s correlation coefficient (see Table 2).

This section presents the results of the correlation between the volume of crime and six spatial indices and their derivations from space syntax theory. The

reason for conducting this exercise is to examine the statistical associations between the spatial properties of the urban space and crime occurrence in the space. The table shows the following items:

**Correlation Coefficient:** A figure between - 1 and +1, indicating direction as well as magnitude of the relationship between variables.

**Significance (Sig., two-tailed):** The p-value, indicating statistical significance of the relationship at the 0. 01 or 0. 05 level (one or two asterisks, respectively).

**Sample Size (N):** Number of samples, i.e., crime hotspots; in the present case, N = 9.

• **Analysis of significant indices**

- **Step depth**

Correlation Coefficient: 0.874\*\*

Significance: 0.002 (significant at the 0. 01 level)

A strong positive correlation was observed between the number of crimes and step depth, meaning deeper spaces—spaces one has to navigate through several intermediate spaces to reach—are more likely to exhibit criminality. This verifies

Table 2. Statistical Comparison of Crime Hotspots with Space Syntax Indices. Source: Authors.

|                        |                         | Correlations |             |            |         |             |              |           |
|------------------------|-------------------------|--------------|-------------|------------|---------|-------------|--------------|-----------|
|                        |                         | Crime_Count  | Integration | Step Depth | Control | Isovis Area | Connectivity | Agentbase |
| Crime_Count            | Correlation Coefficient | 1.000        | -.496       | .874**     | -.507   | -.787*      | -.686*       | -.067     |
|                        | Sig. (2-tailed)         | .            | .175        | .002       | .164    | .012        | .041         | .864      |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |
| Integration            | Correlation Coefficient | -.496        | 1.000       | -.710*     | .369    | .067        | -.109        | -.192     |
|                        | Sig. (2-tailed)         | .175         | .           | .032       | .328    | .864        | .781         | .620      |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |
| Depth_Step             | Correlation Coefficient | .874**       | -.710*      | 1.000      | -.472   | -.561       | -.460        | -.067     |
|                        | Sig. (2-tailed)         | .002         | .032        | .          | .199    | .116        | .213         | .864      |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |
| Spearman's rho Control | Correlation Coefficient | -.507        | .369        | -.472      | 1.000   | .573        | .385         | -.043     |
|                        | Sig. (2-tailed)         | .164         | .328        | .199       | .       | .107        | .307         | .913      |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |
| IsovistArea            | Correlation Coefficient | -.787*       | .067        | -.561      | .573    | 1.000       | .900**       | .300      |
|                        | Sig. (2-tailed)         | .012         | .864        | .116       | .107    | .           | .001         | .433      |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |
| Connectivity           | Correlation Coefficient | -.686*       | -.109       | -.460      | .385    | .900**      | 1.000        | .500      |
|                        | Sig. (2-tailed)         | .041         | .781        | .213       | .307    | .001        | .            | .170      |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |
| Agentbase              | Correlation Coefficient | -.067        | -.192       | -.067      | -.043   | .300        | .500         | 1.000     |
|                        | Sig. (2-tailed)         | .864         | .620        | .864       | .913    | .433        | .170         | .         |
|                        | N                       | 9            | 9           | 9          | 9       | 9           | 9            | 9         |

\*\* . Correlation is significant at the 0.01 level (2-tailed).  
 \* . Correlation is significant at the 0.05 level (2-tailed).

Newman’s (1972) “Defensible Space” hypothesis, which is based on the prediction that isolated or less accessible space is likely to experience crime because natural surveillance and social control decrease in such areas.

**- Isovist area**

Correlation Coefficient: -0.787\*

Significance: 0.012 (significant at the 0. 05 level)

We also found a statistically significant negative correlation between isovist area and crime number, meaning that more open space and unobstructed views are found in areas with fewer crimes. This finding strongly supports Jacobs’ (1961) “Eyes on the Street” hypothesis, which emphasizes that increased visibility and observer presence constrain crime opportunities.

**- Connectivity**

Correlation Coefficient: -0.686\*

Significance: 0.041 (significant at the 0. 05 level)

The analysis indicated a strong to moderate negative correlation between connectivity and the number of crimes. Most connected locales—places that are easier to access from other areas surrounding them—have fewer crimes. This observation once again supports the natural surveillance principle since increased connectivity facilitates pedestrian use and legitimate user presence round-the-clock, which consequently results in fewer offending opportunities.

**• Analysis of Non-Significant Indices**

The other three indices—integration, control, and agent-based movement—did not reveal statistically significant relationships with crime number:

Integration:  $r = -0.496, p = 0.175$

Control:  $r = -0.507, p = 0.164$

Agent-Based:  $r = -0.067, p = 0.864$

From these findings, it can be observed that in this spatial context of the study, these variables exert no quantifiable effect on the distribution of crime.

Therefore, with absolute certainty, it can be stated that step depth, isovist area, and connectivity statistically significantly correlate with crime occurrence. That is, higher step depth corresponds to higher crime rates, while higher isovist areas and higher connectivity correspond to lower crime occurrences. The results concur with available empirical research on environmental criminology and spatial analysis.

However, space syntax map comparison and comparative analysis of cognitive maps certify that crime-prone site determinants are not necessarily physical. Regions with the same syntactic features at times possessed very different degrees of vulnerability to criminality. This certifies the place held by non-physical determinants such as social processes, behavioral patterns, and governance processes in spatial security. As such, the subsequent step in the analytical process categorizes the distribution of root causes of crime to physical and non-physical components with a view to coming up with a general interpretation of environmental security.

## Discussion

### Classification of Locations Associated with Crime and Anomalies

In Phase Four, the spatial division of crime occurrence places was performed based on the degree of conformity or deviation between observations of crime locations and the step depth index, which was created from the analysis using space syntax. The purpose of the exercise was to assess the utility and interpretability of space syntax in defining criminal hotspots. Three groups of spatial segments were created (see Fig. 8).

Group 1 (Segments N1–N6): Spaces A1–A6, being officially recognized locations of crime in cognitive maps, also revealed substantial values

for step depth within space syntax analysis. Their higher crime rates derive from being more spatially deep and bereft of active crime control mechanisms, both aspects reducing opportunities for natural surveillance and increasing exposure to criminal activity.

Group 2: Areas B1–B<sup>5</sup> contained high step depth levels in the space syntax maps, but were not identified as crime sites of occurrence in the cognitive maps. This contradiction shows the efficient use of a crime prevention strategy. These areas include privately owned alleyways where tight territorial control by traders is exercised, controlling access and screening activities within the central courtyards that are semi-private communal spaces. The presence of active guardianship and territorial reinforcement appears to eliminate the probable effect of spatial depth on the crime rate.

Group 3 (Segments N7–N9): Locations C1–C 3 were observed as hotspots of criminal occurrence in the cognitive maps but lacked high step depth in space syntax analysis. This pattern indicates that factors other than space are the primary generators of crime at these sites. But concerted crime control efforts could easily lower the likelihood of future criminal or aberrant activities at these places.

The specific reasons for crime and anomalies at these locations are as follows:

C1: The presence of a blind spot and the absence of natural watching allow criminal and anomalous activities to be prevalent.

C2: Anomalies occur at night when shops are closed down, meaning an absence of active watching and human activity.

C3: Recurrence of crime within this space is due to previous crime patterns of repeated occurrence, which can reverify expectations of behavior of anonymity and lawlessness.

This typology demonstrates how, despite the significant influence of spatial characteristics,

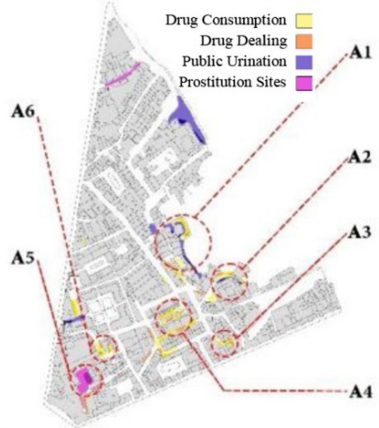
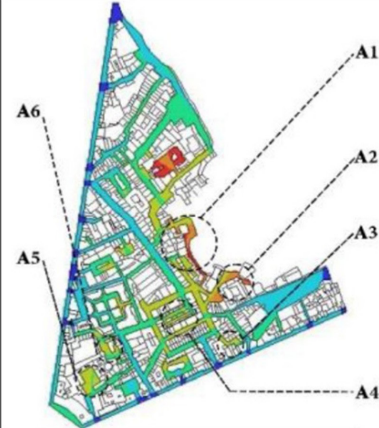
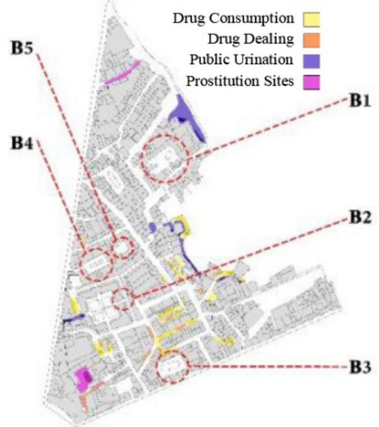
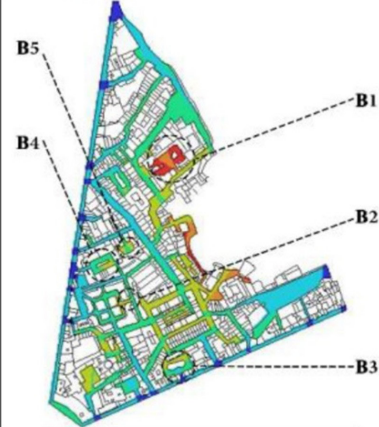
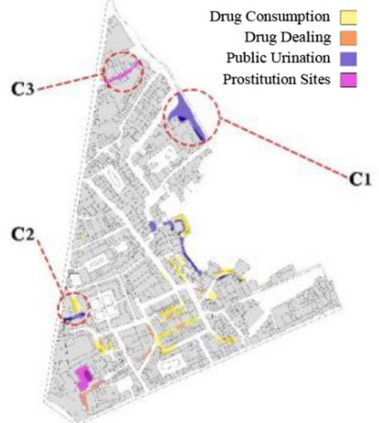

| Comparative Analysis (Step Three)   |   | Classification of Crime Locations (Step Four)  |             | The Functionality of Space Syntax (Step Five) |
|---|---|--|-------------|---|
| Crime Location Identification (Step One)<br>Cognitive Map                           | Space Syntax Analysis (Step Two)<br>Step Depth Index                                | Reason   | Groups      |   |
|    |    | <p>Cognitive Map: Crime incidence exists.<br/>Space Syntax: Exhibits Step Depth.</p> <p>Reasons for the Presence of Crime: Step Depth and the Lack of Appropriate Solutions</p>                            | Group One   | <b>Detectable by software</b>                 |
|   |   | <p>Cognitive Map: No crime incidence exists.<br/>Space Syntax: Exhibits Step Depth</p> <p>Reasons for the Absence of Crime: : Implementing Strategies such as access control and natural surveillance.</p> | Group Two   |   |
|  |  | <p>Cognitive Map: Crime incidence exists.<br/>The Space Syntax: parameter of step depth is absent.</p> <p>Reasons for the Presence of Crime: Failure to Implement Appropriate Solutions</p>                | Group Three |   |

Fig. 8. Overlap between the Cognitive Map and the Step Depth Index. Source: Authors.

particularly step depth, on the spatial pattern of crime, non-spatial circumstances such as surveillance levels, territorial control, temporal activity rhythms, and past trends in behavior are also critical. These findings support a multi-modal

crime prevention approach that integrates spatial design strategies developed from space syntax analysis with social and managerial interventions augmenting surveillance, territoriality, and citizen stewardship.

## Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this research.

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