The Axial Analysis for Defining Neighborhoods' Crime Vulnerability. A Methodological Proposal

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Abstract. One major requirement for well-functioning cities, and for their sustainability, is that they have secure streets and public spaces, as also confirmed by the SDG 11. The work presented here deepens an ongoing research that addresses the issue of urban security in terms of risk. The study is carried out at the neighborhood scale aimed at examining the urban space accessibility and its role in the creation of security conditions. The model uses the *Space Syntax Analysis*, the *TOPSIS method* and *zonal statistic*, for the construction of a ranking and comparison between neighborhoods. The *composite security index* constructed (I_{sa}) allows the identification of the critical conditions in the area examined, identifying neighborhoods that, with respect to optimal accessibility conditions, understood in terms of urban security, are configured as better or worse. The application of the model to the Milan case study has highlighted how within the same territorial context individual neighborhoods can have different responses to the urban crime problem by virtue of their accessibility conditions, delineating possible further research developments.

Keywords: Accessibility · Crime risk vulnerability · Neighborhood security · Space Syntax Analysis · TOPSIS method

1 Introduction

One of the main requirements for well-functioning cities, and for their sustainability [9, 15, 17, 19, 29, 30, 36], is that they have secure streets and public spaces [5, 10, 26]. This circumstance is reaffirmed by the *Sustainable Development Goals* (SDG), in particular SDG 11, by which the creation of secure, as well as inclusive, resilient and sustainable cities is promoted.

Security in the city is hindered everyday by the occurrence of predatory crimes (assaults, thefts or other violent acts) or incivility episodes that affect the perception of insecurity, raising fear and creating, consequently, alienation with respect to the surrounding context [34].

The growing demand for security that citizens ask for requires a new perspective with respect to the approaches that have been adopted so far to deal with this problem. A repressive approach is not sufficient to guarantee effective and long-lasting security

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conditions. It is necessary to focus on an integrated approach in which urban planning plays a fundamental role.

The work presented here deepens an ongoing research that addresses the topic of urban security in terms of risk. In it crime risk is defined as a function of three factors: crime hazard (H_c), crime vulnerability (V_c), crime exposure (E_c) and described through the *Composite Index of crime risk* I_{Rc}, with spatial character [3, 14].

The study starts from an analysis recently developed in which, starting from the crime risk map constructed by applying the model to the city of Milan [14], and adopting a multi-scalar approach, it deepens the link between the accessibility of urban spaces and the vulnerability to crime risk (V_c) [3]. The methodology outlined combines the configurational approach with a multi-criteria method for constructing a ranking at the neighborhood scale and the subsequent comparison between neighborhoods. This allows to identify the neighborhoods that are better or worse compared to optimal accessibility conditions, considered in terms of urban security.

2 Materials and Methods

2.1 Axial Analysis

Space Syntax Analysis [24] allows to describe the accessibility conditions of urban space and simulate the pedestrian movement within it. The focus is on urban space, identified as an intrinsic aspect of human activities and as an essential element in the creation of movement flows [22, 45]. In the configurational theory, the measuring unit is the *visual perspective* connecting two points in space. The preference of one path over another is not based on metric distance but on its articulation.

The analysis of an urban settlement is performed through the urban grid reduction to a system and through the subsequent study of the relationships between its elements. A set of configurational properties assumed as state variables is associated to each of them. The urban grid can be discretized and analysed using a variety of operational techniques: *Linear Analysis*, separated into *Axial Analysis* [21], *Angular Analysis* and *Angular Segment Analysis* [39, 41], *Fragment Angular Analysis* [8]; *Visibility Graph Analysis* (normal and angular) [42]; *Mark Point Parameter Analysis* [7].

Axial Analysis [21] discretizes the urban grid by adopting as an elementary unit of reference the *line* that corresponds to a unit of movement and visual perception. The urban space is schematized and examined by constructing the *axial map.* The latter is composed of the longest axial lines, taken in the smallest number, and it is used as the basic topological map for the calculation of configurational indices: integration index, choice index, connectivity index, controllability index, control value [6].

In detail, the first of them represents the average depth of each line with respect to all the other lines of the axial map and is associated with the *to movement* [20, 22]. The index of choice is a measure of the potential of choice of a line understood as a path in the journey within the system and is associated with the *through movement* [20]. Both parameters are influenced by the axial map size, i.e. the number of lines it consists of. The connectivity index is representative of the number of lines that are directly accessible from the line in question [6].

2.2 TOPSIS Method

The *TOPSIS* (*Technique for Order Preference by Similarity to Ideal Solution*) *method* is a multi-criteria method developed by Hwang and Yoon [25, 28, 46] as an alternative to the *ELECTRE method* of which it is a widely used and advantageous variant [2, 44].

Given a sample of alternatives, the method is based on the assumption that the most convenient alternative is at the least distance from the *ideal* alternative (the best), and at the greatest distance from the *anti-ideal* alternative (the worst). The implementation of the method requires the selection of suitable indices (criteria) to evaluate the alternatives and the definition of a weight to be given to each of them [32].

The procedure is structured in different steps that include: the construction and normalization of the decision matrix; the definition of appropriate weights to be attributed to the indices and the construction of the weighted decision matrix; the definition of the two virtual solutions (*ideal* and *anti-ideal*) and the measurement of the relative distance of each real alternative. The procedure concludes by calculating the *relative closeness coefficient* C_i, based on which the alternatives are ranked. More precisely, in the construction of the ranking, the best alternative is characterized by the highest values of C_i.

3 Model

The model outlined aims at analyzing the accessibility conditions of urban space in relation to its influence on crime risk vulnerability (V_c). The analysis is performed at the neighborhood scale, since some key security issues, including accessibility [3] can only be captured through the study of limited-sized areas.

The methodology allows to describe and compare the accessibility conditions of neighborhoods, combining the configurational approach with a multi-criteria method and performing analysis on two spatial levels of reference:

- *Level 1 – accessibility by axial line;*
- *Level 2 – accessibility by neighborhood.*

In particular, it involves the use of Axial Analysis, the TOPSIS method, zonal statistics and is divided into three macro-phases.

The first of these analyzes the accessibility conditions of urban space using Axial Analysis [21] and the calculation of three configurational parameters: integration index (global and local), choice index (global and local), connectivity index. In the context of the analysis, *global* refers to the application to a spatial area containing a defined set of lines, while *local* refers to the measurement related to a surrounding of each line.

Analysis is followed by the systematisation, normalisation and weighing of the index values obtained and a first comparison of the accessibility conditions described by each configurational parameter.

The second macro-phase is dedicated to the implementation of the TOPSIS method [25] to construct a ranking of accessibility values and a first comparison between neighborhoods in relation to Level 1. The selected criteria for the analysis of alternatives are

five and correspond to the configurational indices (global and local) calculated in the first macro-phase. For each area are used the normalized values of the indices for each line, weighted by the lines length, in global and local form. The ranking is constructed considering all the lines that constitute the axial maps of the examined neighborhoods.

The third macro-phase is implemented on Level 2, for which the areas examined are ranked using zonal statistics based on the ranking obtained on Level 1. For this purpose, the lines examined are classified into 5 criticality classes, with increasing intensity from very low (1) to very high (5). The classes are constructed according to the values of the relative proximity coefficient C_i, obtained in the previous macro-phase. More precisely, low criticality conditions are associated to lines with high values of C_i coefficient, representing positive conditions of accessibility and security, vice versa for lines in class 5. Indeed, accessibility is closely linked to crime risk vulnerability, since it influences the possibilities of informal control of the territory. Urban spaces with high values of accessibility and visual permeability, combined with a regular urban grid, encourage the presence of people on the street who act as potential "eyes on the street" [3, 26].

Attention then turns exclusively to the lines included in classes 1 and 5. In relation to these last ones, the model evaluates, for each class (c), and referring to the lines length ($l_{j,c}$ with j = 1,…, m and c = 1, 5): the minimum value (l_{min}), the maximum value (l_{max}), the average value (l_{av}), the standard deviation (l_{sd}) and the overall sum of the lines lengths (L_c).

Therefore, the study of accessibility conditions is deepened by introducing two security indicators. The first of these represents the density of critical lines, class 5, for each neighborhood under study, D_{cl}:

$$D_{cl_i} = \frac{L_5}{A_i} = \frac{\sum_{j=1}^{m} l_{j,5}}{A_i}$$

with:

- D_{cl_i} = density of critical lines, class 5, in the i neighborhood (with i = 1,…, n);
- $L_5 = \sum_{j=1}^{m} l_{j,5}$ = sum of lengths of the m critical lines, class 5, of the i neighborhood;
- A_i = area of the i neighborhood under study.

High values of the indicator are representative of critical conditions. They highlight the presence, in the neighborhood examined, of a high density of lines with very low accessibility values and, therefore, critical regarding security.

The second indicator describes the criticality rate of lines. It is evaluated as ratio between the total length of the critical lines (class 5) and that of the lines with positive values (class 1), R_{cl}:

$$R_{cl_i} = \frac{L_5}{L_1} = \frac{\sum_{j=1}^{m} l_{j,5}}{\sum_{z=1}^{k} l_{z,1}}$$

with:

- R_{cl_i} = criticality rate of lines in the i neighborhood (con i = 1, …, n);

- $L_5 = \sum_{j=1}^{m} l_{j,5}$ = sum of lengths of the m critical lines, class 5, of the i neighborhood;
- $L_1 = \sum_{z=1}^{k} l_{z,1}$ = sum of lengths of the k positive lines, class 1, of the i neighborhood.

High values of the indicator represent critical conditions. They highlight the prevalence of critical lines compared to lines with positive accessibility values in terms of vulnerability and, therefore, security.

The computation of these security indicators is followed, then, by their spatialization and combination into a composite index, with spatial character, I_{sa}:

$$I_{sa} = I_{sa}(D_{cl};\ R_{cl})$$

The indicators are combined with each other using a matrix approach. The model involves the use of reclassification and overlay mapping between rasters, fundamental map-algebra operations [38], implemented from the base maps.

To this purpose, for each of the neighborhoods examined, the n values of the two indicators (D_{cl_i} and R_{cl_i} = with i = 1,…,n) are reclassified into 5 classes of criticality, as before. Through the overlay mapping a combination matrix is built in which each cell, defined according to the logical Boolean operator AND, identifies a specific class of criticality according to the accessibility values. Based on this principle and according to risk matrix logic [11–14], it is possible to interpret and reclassify the combination results by constructing 5 criticality classes related to accessibility values: very low (CA1), low (CA2), moderate (CA3), high (CA4), very high (CA5).

The *composite security index* thus constructed, I_{sa}, allows the identification of the critical conditions in the area examined, highlighting the potential of individual neighborhoods to provide an answer to the urban crime problem by virtue of their accessibility conditions. The most problematic conditions, which need attention, are found at class CA5.

4 Application of the Model

The outlined methodology was applied to the case study of Milan. It deepens and integrates a previous study that led to map the risk conditions of the city [14] and study the link between accessibility and crime risk vulnerability [3].

According to the paper's objectives, the application involved 31 neighborhoods selected among the *Nuclei di Identità Locale* (NIL) which correspond to local identity cores, defined by the *Piano di Governo del Territorio* (PGT-Milano 2030) which correspond to the urban Plan of Milan (Fig. 1). The 35 NILs to be analysed were chosen according to the presence of medium (R3), high (R4) and very high (R5) crime risk classes (Fig. 1) and according to land use. Only neighborhoods with a mainly residential land use category, with grid layout and irregular layout, were included in the analysis [3]. In detail: 1-Duomo; 2-Brera; 3-Giardini Pt. Venezia; 4-Guastalla; 5-P.ta Vigentina, P.ta Lodovica; 6-P.ta Ticinese, Conca del Naviglio; 7-Magenta, S. Vittore; 8-Parco Sempione; 9-P.ta Garibaldi, P.ta Nuova; 10-Stazione Centrale, Ponte Seveso; 11-Isola; 12-Maciachini, Maggiolina; 20-Loreto, casoretto, NoLo; 21-Buenos Aires, P.ta

Venezia, P.ta Monforte; 22-Città studi; 25-Corsica; 26-XXII Marzo; 27-P.ta Romana; 28-Umbria, Molise, Calvairate; 44-P.ta Ticinese, Conchetta; 50-P.ta Genova; 51-P.ta Magenta; 52-Bande Nere; 57-San Siro; 58-De Angeli, Monte Rosa; 59-Tre Torri; 68-Pagano; 67-Portello; 69-Sarpi; 70-Ghisolfa; 71-Villapizzone, Cagnola, Boldinasco; 77-Bovisa; 78-Farini; 79-Dergano; 80-Affori. Some areas consist of 2 NILs, due to the continuity of the urban structure.

The area of interest corresponds to the central ring of the Milan consolidated fabric. As stated in the PGT-Milano 2030, it is characterized by a very high urbanization and high accessibility, in some cases equal in size to 100% of the NIL surface.

In the PGT-Milano 2030 zoning it is characterized by the presence of *Nuclei di Antica Formazione* (NAF) which correspond to cores of ancient formation, external historical cores, pedestrian spaces and squares. These are 5 of the 7 squares with high accessibility, for which the PGT-Milano 2030 envisages regeneration interventions aimed at improving design quality, pedestrian accessibility and attractiveness. There are *Ambiti di Rinnovamento Urbano* (ARU) which correspond to urban renewal areas and Environmental Regeneration Areas alongside existing and new urban green spaces. Moreover, the NIL 78-Farini, is characterized by the presence of a railway yard where a new urban park and some social housings are to be built.

Almost all of the selected NILs, in addition, are affected by regeneration and transformation interventions, planned or partially implemented, aimed at increasing urban green areas, services and environmental regeneration of the urban fabric.

Moreover, several changes of land use are foreseen, characterized by a significant increase of the residential land use category and by the introduction of accomodation functions, replacing part of the commercial, tertiary and productive land uses[1].

The application of the model was divided into successive steps. The first of these has regarded the implementation of the Axial Analysis on the selected neighborhoods. For this purpose, for each of the 31 neighborhoods examined, the urban grid was represented, by vector editing functions carried out starting from the basic cartography.

In the construction of the latter, it was chosen to exclude and consider not freely accessible: parks, playgrounds, railway lines, subways and highway connections. Then, through the Depthmap software [40], the topological base map was obtained and configurational indices with global (R = n) and local (R = 3) valence were calculated. In addition, in order to make the accessibility values of the examined neighborhoods comparable, it was necessary to disassociate the integration and choice indexes from the axial maps dimension through a normalization step. The first of them, in particular, was normalised using the concept of Real Relative Asymmetry-RRA, through the Krüger's formulation [27].

The results were systematized in a summary table and weighted according to the lines' length. This allowed an initial evaluation of the accessibility values recorded for each line and helped the next steps to be taken.

The second macro-phase was conducted by implementing the TOPSIS method on the spatial reference Level 1. The five configurational measures used as analysis criteria are: Global Normalised Integration Index, RRA(R = n); Local Normalised Integration

[1] For further information please consult the PGT-Milano 2030, available at the link: https://www.pgt.comune.milano.it/ (accessed 21/04/2021).

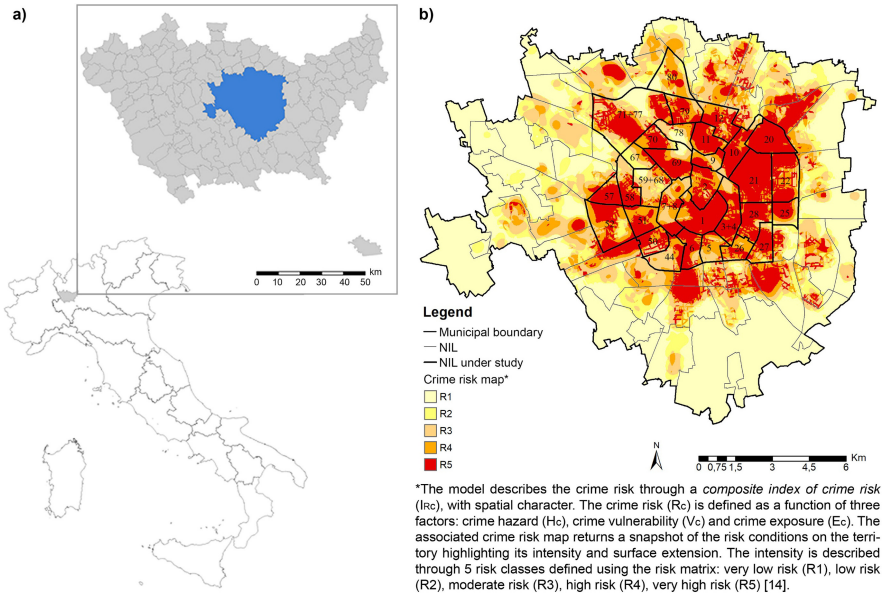


Fig. 1. a) Territorial context of the study area; b) Milan municipality's crime risk map. Source: authors' elaboration.

Index, RRA(R = 3), Global Normalised Choice Index (R = n); Local Normalised Choice Index (R = 3); Connectivity Index. The analysis was performed considering for each index (global and local) the values of all lines of the 31 axial maps under study, with 2499 lines in total (Fig .2).

The analysis was conducted with equal weights and the value judgment, representative of ideal and anti-ideal accessibility conditions, was constructed, for each index, according to the relevant performance scale. In detail, the normalization criterion used for the integration index, both global and local, cause its values to range between 0 (ideal accessibility) and values greater than 1 (segregation). Therefore, the minimum value was set as ideal condition and maximum value as anti-ideal. The normalized choice index, both global and local, ranged between 0 (low *through movement*) and 1 (high *through movement*). Consequently, the ideal condition was associated with the maximum value and the anti-ideal with the minimum. The same judgment criterion was used for the connectivity index.

The third macro-phase concerned the realization of zonal statistics in a GIS environment, through the use of ArcGIS software [18], on Level 2, starting from the ranking obtained in Level 1. To this purpose, the lines under study were classified on the basis of the C_i coefficient values into 5 criticality classes, with increasing intensity from very low (1) to very high (5). These classes were constructed using the *Natural Breaks* setting. Among the 2499 values examined, only those belonging to classes 1 and 5 were extracted for each neighborhood. For the latter, with reference to the length of the lines (l), were evaluated: the minimum value (l_{min}), the maximum (l_{max}), the average value (l_{av}), the standard deviation (l_s) and the overall sum of the lines lengths (L_c) (Table 1).

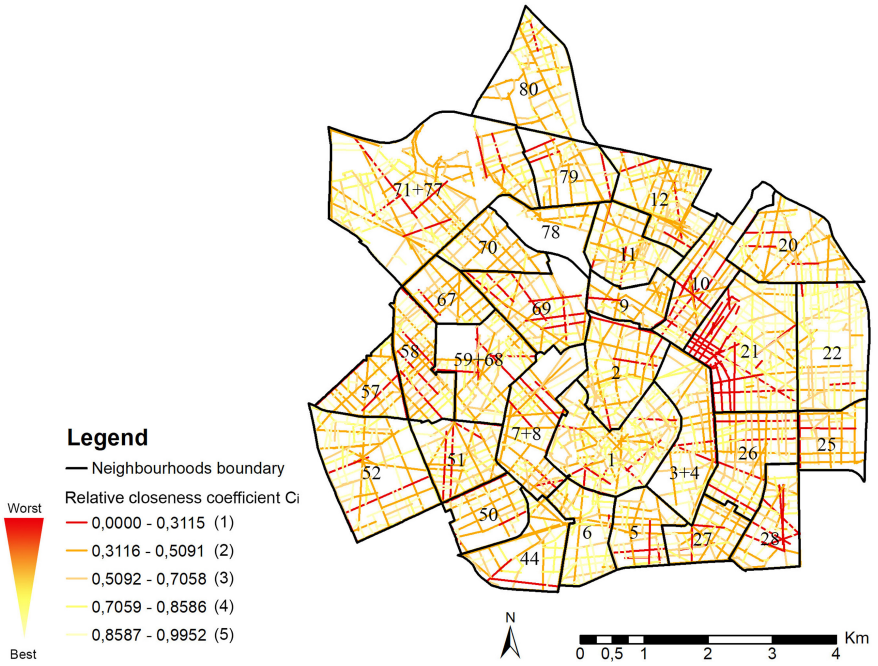


Fig. 2. Ranking of accessibility values for axial line (Level 1). Source: authors' elaboration.

Next, the following were calculated for each of the areas: the density of critical lines (D_{cl_i} with i = 1,…,31) and the criticality rate of lines (R_{cl_i}, with i = 1,…,31). The values obtained were reclassified into 5 classes of criticality, with increasing intensity from 1 to 5, and spatialized in order to allow their combination (Fig. 3 and 4). The resulting base maps were combined using an overlay mapping operation, and the results were interpreted using the matrix of critical accessibility levels (Fig. 5), structured following the logic of the risk matrix [14]. The criticality classes built through this matrix cannot be generalized but are only valid for the case study of Milan.

The map associated with the composite index of security thus constructed, I_{sa}, is shown in Fig. 6.

Table 1. Results of statistical analysis performed by neighborhood (Level 2). Source: authors' elaboration.

NIL	Area	Lines – class 1				Lines – class 5			
		l_{min}	l_{max}	l_{av}	l_{sd}	l_{min}	l_{max}	l_{av}	l_{sd}
(ID)	(km^2)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	2,3	35,2	476,3	130,9	74,7	313,2	881,8	520,8	169,4
2	1,6	36,9	619,7	163,0	110,2	571,6	1074,9	725,7	237,6
3 + 4	1,6	67,6	386,0	178,4	83,6	620,3	1522,4	936,2	347,5

(*continued*)

Table 1. (*continued*)

NIL	Area	Lines – class 1				Lines – class 5			
		l_{min}	l_{max}	l_{av}	l_{sd}	l_{min}	l_{max}	l_{av}	l_{sd}
5	1,0	10,7	708,3	205,6	149,3	379,6	896,5	673,8	195,4
6	1,2	34,9	976,2	238,9	202,6	181,7	378,7	280,2	139,3
7 + 8	0,5	55,4	753,3	187,7	144,7	440,0	917,5	671,7	159,6
9	0,8	24,4	418,5	178,6	96,7	306,8	648,9	543,2	130,7
10	1,6	10,0	738,6	253,0	162,4	508,3	1624,5	974,9	340,0
11	1,3	24,4	539,2	176,5	131,6	646,7	1132,8	769,5	242,2
12	1,7	63,9	643,6	186,1	112,5	122,2	854,4	508,2	313,4
20	1,8	39,8	469,8	190,5	84,1	478,1	724,7	583,1	127,3
21	2,9	131,2	2016,7	684,9	599,3	95,9	1951,2	543,6	414,7
22	2,1	66,1	1996,2	462,2	406,3	109,7	412,4	242,1	154,9
25	1,0	67,7	503,3	195,2	101,3	892,3	924,0	908,1	22,5
26	1,6	68,1	520,9	242,5	119,9	812,7	1300,6	958,8	192,2
27	0,9	85,5	491,7	232,3	114,7	497,3	706,7	617,8	70,2
28	1,2	68,1	506,3	225,5	123,2	572,9	1034,7	784,8	146,5
44	1,4	25,6	361,1	190,8	89,1	513,2	1073,6	819,0	283,7
50	1,1	15,7	339,9	151,0	85,9	371,4	1140,1	587,5	369,9
51	1,3	58,5	345,3	213,0	72,9	648,3	1239,5	985,8	255,5
52	2,7	81,4	695,2	236,4	129,0	692,7	1465,1	1195,8	436,1
57	1,0	72,4	554,8	212,0	132,0	643,8	1227,7	930,3	259,1
58	1,3	55,9	499,6	208,2	98,0	682,1	1073,1	852,0	147,7
67	0,9	166,4	434,4	303,1	115,7	512,5	831,3	671,9	225,5
59 + 68	1,3	44,2	803,9	197,9	156,1	576,3	901,0	762,7	136,3
69	1,8	74,0	367,5	182,7	77,1	516,9	986,0	782,9	152,3
70	1,0	68,0	512,4	235,1	125,7	0,0	0,0	0,0	0,0
71 + 77	5,4	45,5	948,3	223,3	164,2	542,0	1633,9	959,6	466,9
78	1,1	73,9	322,9	194,6	73,8	0,0	0,0	0,0	0,0
79	1,3	43,6	336,5	196,3	74,0	503,7	864,6	632,1	201,7
80	2,1	57,9	1255,3	271,9	231,4	485,9	485,9	485,9	0,0

5 Discussion of Results

The results obtained from the axial analysis performed at Level 1 show a heterogeneous situation with regard to the accessibility values recorded for the 31 neighborhoods examined.

In detail, the highest values of local and global integration, 0,095 and 0,098, occur in lines belonging to NIL 9 and 21, respectively. The lowest values, equal to 4,788 and 1,212, are identified in lines of NIL 1 and 50. The neighborhoods in which high accessibility conditions are observed, with more than 50% of lines whose global integration values are lower than the average value, correspond to NIL: 1, 2, 3 + 4, 6, 7 + 8, 9, 10, 11, 12, 21, 22, 26, 27, 51, 52, 69. The same situation, in local terms, is noted in all the areas examined, except for NIL 1 and 71 + 77. The values of the choice index range from a minimum of 0, observed in some lines of all the areas examined, to maximum values, in global and local terms, equal to 0,879 and 0,667 measured in lines belonging respectively to NIL 80 and 50. Neighborhoods where conditions of high accessibility are observed, associated with a high potential for through movement, with more than 50% of lines whose overall choice values exceed the mean value, correspond to NIL: 9, 70, 78. The same circumstance, in local terms, is in NIL: 9, 67, 70, 78, 79. As regards connectivity, 16 of the 31 neighborhoods examined (NIL: 2, 3 + 4, 5, 7 + 8, 9, 10, 12, 25, 28, 44, 50, 52, 69, 71 + 77,78, 80) present lines in which a minimum value of 1 is recorded, while the maximum value, equal to 33, is found in NIL 21. High accessibility conditions, with more than 50% of lines whose connectivity values exceed the average value, are found in NIL: 10, 21, 22, 26, 27, 51.

The ranking construction at Level 1 led to the identification of the best and worst lines in relation to accessibility conditions, with reference to urban security [3]. The ranking presents values of the relative closeness coefficient C_i ranging between the minimum value (worst condition) of 0 and the maximum value (best condition) of 0,9952 (Fig. 2). The subsequent construction of 5 criticality classes for the 2499 lines under attention highlights the presence of: 155 lines in class 5, 444 in class 4, 423 in class 3, 551 in class 2 and 926 in class 1. Examining the data globally, lines characterized by positive values appear to predominate, however the effect that poor accessibility generates on neighborhoods, in terms of security, requires an analysis on a neighborhood-by-neighborhood basis.

Starting from this result, the analysis conducted on Level 2 has made it possible to evaluate in greater detail the conditions of accessibility of the areas examined. It highlighted the real incidence of lines with critical values both in relation to the NIL surface extension, and to the presence of lines with positive values (Figs. 3 and 4). In particular, the density of critical lines, D_{cl}, ranges from a minimum of 0 at NIL 70 and 78, where no class 5 lines are present, to a maximum of 0,0086 at NIL 7 + 8. The criticality rate of lines, R_{cl}, has a minimum value of 0, at NILs 70 and 78, for the reasons just stated, and a maximum value of 91,3627 at NIL 69.

The maps obtained from the reclassification and spatialization of the two indicators (D_{cl}; R_{cl}) (Figs. 3 and 4) show that, in terms of critical line density, the most critical areas are represented by NIL: 7 + 8, 10, 21 and 28. In relation to the rate of critical lines the most critical areas are NIL 1 and 69.

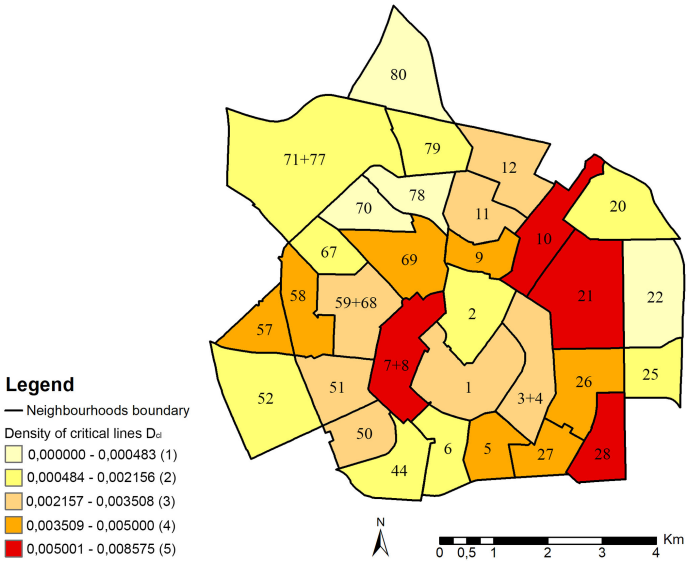


Fig. 3. Spatialization of critical line density values, D_{cl}, by neighborhood (Level 2). Source: authors' elaboration.

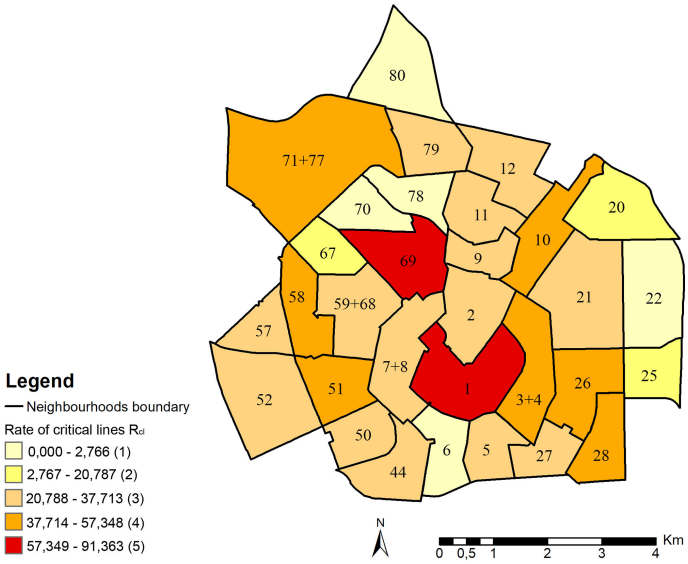


Fig. 4. Spatialization of critical lines rate values, R_{cl}, by neighborhood (Level 2). Source: authors' elaboration.

a)

Critical Accessibiliy classes		D_{cl} classes				
		$D_{cl}1$	$D_{cl}2$	$D_{cl}3$	$D_{cl}4$	$D_{cl}5$
R_{cl} classes	$R_{cl}1$	11	12	13	14	15
	$R_{cl}2$	21	22	23	24	25
	$R_{cl}3$	31	32	33	34	35
	$R_{cl}4$	41	42	43	44	45
	$R_{cl}5$	51	52	53	54	55

b)

Critical Accessibiliy classes		D_{cl} classes				
		$D_{cl}1$	$D_{cl}2$	$D_{cl}3$	$D_{cl}4$	$D_{cl}5$
R_{cl} classes	$R_{cl}1$	CA1	CA1	CA2	CA3	CA4
	$R_{cl}2$	CA1	CA2	CA3	CA4	CA5
	$R_{cl}3$	CA2	CA3	CA3	CA4	CA5
	$R_{cl}4$	CA3	CA4	CA4	CA5	CA5
	$R_{cl}5$	CA4	CA5	CA5	CA5	CA5

Fig. 5. a) Critical accessibility levels construction matrix for the Milan case study; b) Matrix of critical accessibility levels for the Milan case study. Source: authors' elaboration.

Finally, looking at the mapping associated with the composite security index, I_{sa}, (Fig. 6), it is possible to identify the most critical neighborhoods considering both the density and the rate of critical lines. For the case study examined this circumstance is found in the areas made up of NIL: 1, 7 + 8, 69, 58, 10, 21, 26, 28. The accessibility conditions of the latter negatively affect the possibility of exercising informal control, making them more vulnerable to crime. They require further study and the definition of specific strategies and actions to reduce vulnerability and, consequently, crime risk.

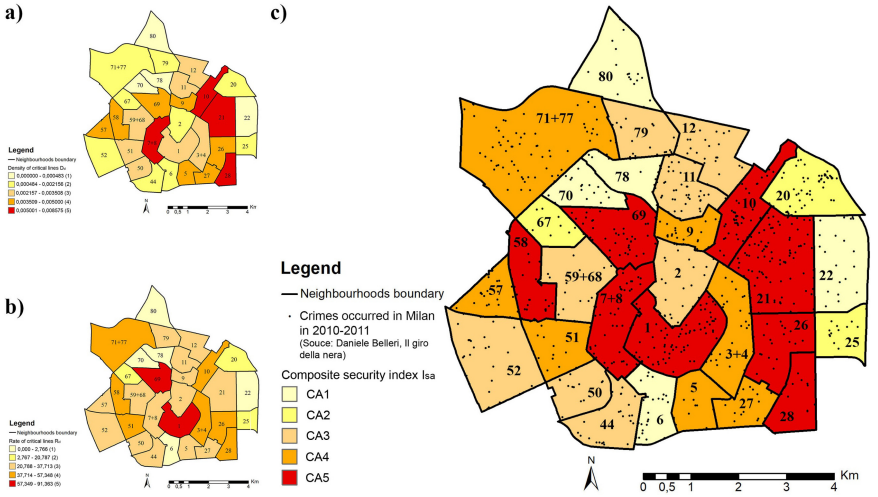


Fig. 6. a) Spatialization of critical line density values, D_{cl}, by neighborhood (Fig. 3); b) Spatialization of critical lines rate values, R_{cl}, by neighborhood (Fig. 4); c) Spatialization of the composite security index, I_{sa}, based on the matrix of critical accessibility levels (Level 2). Source: authors' elaboration.

6 Conclusions and Prospects

The application of the model to the Milan case study has highlighted how within the same territorial context individual neighborhoods can have different responses to the issue of urban crime. In detail, this response was examined considering a physical aspect of urban space, namely accessibility understood in topological terms, as the ease by which a space can be reached by others. This characteristic, as mentioned above, can influence crime vulnerability by affecting the possibility of exercising informal surveillance. Urban spaces with high values of accessibility and visual permeability, combined with a regular urban grid, encourage the presence of people on the street, residents and non-residents, who act as potential "eyes on the street" [3, 26].

The analysis of neighborhood accessibility was performed using a configurational approach combined with a multi-criteria method in order to examine the characteristics of the individual lines under study. The composite security index, I_{sa}, obtained after the implementation of zonal statistics, allows for an assessment on a neighborhood scale. In fact, it describes the critical conditions of the neighborhood examined, considering both the critical lines density and the prevalence (or not) of the latter compared to the lines with positive accessibility values in terms of crime vulnerability and urban security. The mapping associated with it allows for the rapid identification of neighborhoods with greater criticality in relation to the phenomenon studied and in need of attention. The model outlined is also suitable to be applied to different territorial contexts from the one examined.

The results obtained suggest possible further developments of the research. The work presented here is oriented to understand a complex phenomenon that, as such, requires a deepening and the introduction of further analysis and variables of a physical, functional and social nature. In fact, the beneficial effect of accessibility on crime risk vulnerability is influenced by multiple aspects, including: the presence of residential units on both sides of streets; intervisibility between dwellings; a proper, consciously structured functional mix in which the residential function is calibrated to balance the vulnerability created by other uses, etc. [3, 16, 23, 33, 35, 43]. The balance between these factors is fundamental to facilitate the possibility of informal control which, however, will be implemented with more or less relevance depending on the socio-cultural context of the place and the citizens' lifestyle. Informal surveillance is more likely to be practiced where walking is a consolidated habit [31]. In the absence of the aforementioned requirements, high accessibility could have the opposite effect, as it is also correlated to the offender's greater awareness and freedom of action, greater ease of approach to potential victims, and the presence of greater escape routes for criminals [1, 16, 23, 37].

Specifically, in relation to the case study, the overlap between the composite security index, I_{sa}, and the spatial distribution of crimes (Fig. 6) qualitatively highlights a positive effect of accessibility on vulnerability. The presence of higher crime events is perceived at the highest levels of critical accessibility (CA4 and CA5). This observation leads to include, among future research developments, a quantitative analysis of the relationship between the crime level and the spatial configuration of neighborhood units in Milan.

Based on the observations made, it is necessary to emphasize the importance of considering urban security when defining urban planning tools. It appears clear that planning choices can significantly affect the conditions of vulnerability and exposure to crime risk.

With reference to the case study examined, in particular, the PGT-Milano 2030 foresees urban requalification interventions, changes of use, etc., without considering the effects that such choices may have in terms of crime risk. For instance, the *External Istorical Cores* and *Pedestrian Areas*, for which the PGT-Milano 2030 (NTA, art. 15) [4] foresee as a form of regeneration the realization of any urban function or an increase in neighborhood shops, craft activities (with regard to personal services and those in the food and non-food sectors) and service activities (in which are also included basements, semi-basements and mezzanines if functionally and physically connected, located on the ground floor overlooking the public plane and/or public use. Such predictions can alter the functional mix, which is a major factor in security because it can influence the cities' vitality and informal surveillance of urban space [14]. In addition, many of the neighborhoods examined are affected by medium and long term forecasts that will modify the accessibility conditions, as understood in the present contribution, through the increase of paths and pedestrian areas, without taking into account the influence this has on crime vulnerability and, therefore, on urban security [3]. In conclusion, it is observed that the possibility of promoting neighborhood security is closely linked to the definition of a suitable framework of rules to be constructed downstream of the risk scenario simulation resulting from the planning choices. This could be made possible by introducing the crime risk map [14] among the knowledge documents in the ex-ante phase of the urban Plan formation.

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