

Milan: The Configuration of a Metropolis



Valerio Cutini, Denise Farese and Giovanni Rabino

Abstract The configurational approach to the study of urban settlements has been largely debated in the last years, gaining a wide audience and a full recognition as a useful and reliable tool for the analysis and the comprehension of the inner geography of cities. Milan, whose diachronic genesis was never before analysed by means of a configurational approach, appears a peculiar and outstanding case study, as its complex structure, actually difficult to read, has undergone significant changes over time; a broad and varied sequence of projects, developments and planning choices have materialized and interiorized within the whole grid of the settlement, from its inner nucleus up to the external edges. Yet, the purpose of this research goes even beyond the mere understanding of the diachronic genesis of the inner geography of Milan, anything but easy, due to the dimension of the settlement and to its internal complexity. The configurational analysis is here also shown as an excellent planning tool, suitable for supporting the decision-making process of urban actions and projects, with a particular reference to those involved with to the theme of accessibility, so as to usefully orient the present and future planning of public spaces. The results show that the space syntax approach actually enhances the transparency of strategic decisions concerning the design and planning of urban spaces, making to emerge and highlighting their likely effects on a wide range of aspects and phenomena.

V. Cutini (✉)
DESTEC, University of Pisa, Pisa, Italy
e-mail: valerio.cutini@ing.unipi.it

D. Farese
Politecnico of Milan, Milan, Italy

G. Rabino
DASTU, Politecnico of Milan, Milan, Italy

1 Introduction

The configurational approach to the study of urban settlements has been largely debated in the last years, gaining a wide audience and a full recognition as a useful tool of urban space analysis. An amount of studies and researches have highlighted the innovative capacity of the method and demonstrated its reliability, as well as proving its potential in complementing more common and traditional methods of spatial analysis.

The inner geography of Milan, whose diachronic genesis was never before analysed by means of a configurational approach, appears a peculiar and outstanding case study, as its complex structure, actually difficult to read, has undergone significant changes over time; a broad and varied sequence of projects, developments and planning choices have materialized and interiorized within the whole grid of the settlement, from its inner nucleus up to the external edges.

But this is not merely an exercise of urban reading, aimed at understanding the diachronic analysis of the system, reconstructing the evolution and shifting of the levels of urban centrality over time, and interpreting the distribution of activities and centrality levels within the city of Milan; what moreover is anything but easy, nor simple, due to the dimension of the settlement and to its internal complexity. In this study, the configurational analysis is also shown as an excellent planning tool, suitable for supporting the decision-making process of urban actions and projects, with a particular reference to those involved with to the theme of accessibility, usefully orienting the present and future planning of public spaces. The results show that the space syntax approach actually enhances the capability of strategic decisions concerning the design and planning of urban spaces.

2 Methodology

The configurational approach to the analysis of urban settlements was introduced by Bill Hillier in the late 1970s to early 1980s under the name of space syntax, as a tool to help urban planners simulate the likely social effects of their designs; since then, the theory and the techniques have been advanced and developed by a large community of researchers all over the world.

The configurational analysis focuses on space, as it results defined by the blocks and building aligned along the streets that compose the grid of the urban settlement, which can be broken down into components, suitable to be analyzed as a network of discrete elements, to be represented by graphs that describe the relationships of each of those spaces with all the others. The general idea is that the grid of the urban paths is assumed as the primary element in determining the patterns of socio-economic behaviour of humans (Hillier 1996), which aims at taking benefit of the flows of through movement connecting its spaces; within such movement, a part, named natural movement, is assumed as merely depending on the grid configuration

and not affected by the presence of the activities along its paths (Hillier et al. 1993). The analysis is expected to provide each element of the system with values that correspond to a set of numeric parameters, named configurational indices. Such indices are called configurational, in that they are calculated taking into account only the relationships between each element and all the others, thus excluding any interest in its geometric or morphologic features. Such aspect suggests to represent the spatial system by means of a graph, whose single node corresponds to a spatial element and each edge corresponds to a direct connection with another element. Such representation highlights that the computation of the connections and mutual depth between elements (or nodes) has to adopt a topologic approach, disregarding the metric features of the settlement.

Among the several configurational techniques so far introduced, distinguishing each other for the way of discretizing the urban space, the so-called axial analysis and visibility graph analysis are by far the most used. The research this paper is concerned with the use of axial analysis, whose system, named axial map, is constructed reducing the space of the settlement into the set of the longest and fewest accessible lines, called axial lines, that cover the whole grid and connect each of its convex spaces. The other technique distinguishes for reducing the grid into a system of vertices, called visibility graph, mutually related each other by visual interconnection.

The configurational indices extracted from the analysis of the grid have been demonstrated suitable for narrowly reproducing some significant urban phenomena or aspects (more or less directly) concerned with the presence of movement. A first parameter is the connectivity value, reproducing the number of elements (either lines or vertices) directly connected with the observed one, and corresponding to the parameter that in graph theory is usually defined as grade. Among the most significant of the other parameters, the integration value (corresponding to the closeness index in graph theory) is defined as the mean depth of the observed spatial element from all the others within the grid, that is:

$$D_M(x) = 1/n \sum_{i=1}^n D(x, i)$$

Also expressed (and calculated) by the mean number of turns along the shortest path connecting the element to all the others, the integration value was strongly demonstrated to correspond to the distribution of retail activities. The set of the elements provided with the highest integration values compose the so-called integration core, which can be used as an effective spatial indicator of urban centrality. The same analysis can also be declined in an angular version, called angular analysis, which takes into account, in addition to the number of intersections, also their respective mutual angle of incidence, as follows (Turner 2007):

$$D_{\theta M}(x) = 1/n \sum_{i=1}^n D_{\theta}(x, i)$$

Another significant configurational index is the choice value, corresponding to the parameter that in graph theory is commonly defined as betweenness, expressing

the frequency of a spatial element (again, either line or vertex) along the shortest paths connecting all the couples of other elements, what in analytical terms can be written as follows (Turner 2007):

$$Ch_x = \sum_{i=1}^n \sum_{j=1}^n \sigma(i, x, y) \quad \text{being } i \neq x \neq y$$

Both those parameters can be usefully expressed in relative terms, normalized with respect to the number of spatial elements, that is the dimension of the grid, and both them can also be calculated taking into account all the elements of the grid (obtaining global integration and global choice, respectively) as well as only the neighboring elements, so as to obtain the local integration and choice value. Observing the correspondence of global and local indices allows appraise the relationship between the whole urban system and the single parts that compose it. In particular, the R^2 determination coefficient of the correlation between global integration and local integration is commonly called synergy coefficient; a high value, approaching 1, is expected standing for a narrow anchorage of the local subsystems to the global one, in that the most integrated elements of the grid are also prime local integrators, that is central elements at a local scale.

An amount of researches actually demonstrates that choice value narrowly corresponds to the distribution of movement (either vehicular movement and pedestrian one) (among others: Hillier and Iida 2005).

Connectivity value, integration value and choice value can all be regarded as indices of centrality, assuming the notion of urban centrality under different meanings. Spatial elements provided with high connectivity values will be expected to be a prominent local pivot; high values of integration will stand for highly attractive areas with reference to the location of economic activities, to be regarded as an ideal destination of movement as meanly easily accessible from any part of the settlement; high values of choice will then characterize spatial elements interested by dense movement, and hence attractive locations for activities aimed at intercept through movement flows.

3 Diachronic Analysis of the City

In order to carry on the analysis of settlement genesis of Milan by means of a configurational approach, three different dates have been chosen, suitable for representing the development of spatial expansion of the system over time: 1704, 1884, 2014. The first map is a representation of the city of Milan at the time of the Austrian domination (Fig. 1); the second one shows engineer Beruto's town plan in 1884 (Fig. 2); the last map is representative of the city of Milan nowadays (Fig. 3).

Every map has been digitalized and analysed by space syntax; interesting outputs have come from the observation of integration core, in that it allows determine the evolution of urban centralities over time (Cutini 2001). Centrality is a key factor

Fig. 1 Integration core of Milan at 1704



Fig. 2 Integration core of Milan at 1884



in shaping both urban space and urban life; the integration core, that should reflect centrality, may present various features as Bill Hillier suggests: “The core takes a form typical of many types of town or urban area, which we call deformed wheel. A small semi-grid of lines in the heart of the settlement (the hub) is linked in several directions (the spokes) to lines on the periphery of the settlement (the rim), which also form part of the core” (Hillier 1996).

The city of Milan in 1704 is extremely restricted into a medieval form within a circle of about three kilometres; the integration core seems to be linear and developed within adjacent and central streets where historically commercial activities were concentrated. The urban expansion in the late 1800s led to a decentralization of the centrality due to the first urbanization expansion over the boundary walls; in the

second map, the integration core appears composed of the main axes that connect the peripheral zones of the city to the centre. This spatial analysis reflects the aspiration and spatial strategy expressed by Cesare Beruto in his plan of 1884 of developing a radial structure inside the city of Milan.

Since the early 1900s, the city of Milan has undergone strong changes over time in terms of urban development, population growth and industrial progress, gaining an area of about 182 kilometres. The main characteristic highlighted by the spatial analysis of the city in Milan in 2014 is the multiple centrality structure due to the new urban approach based on a functional mix (Oliva 2002). Mixed-use development aims to reduce the need for travel, to increase walkability and generate street-life intensity; it blends residential, commercial, cultural and industrial uses, where functions are physically and functionally integrated. Differently from the previous maps, in the last one several centralities turn out as the image (Fig. 3) shows.

Integration Cores:

1. Duomo
2. Brera-Garibaldi
3. Centrale
4. Porta Romana
5. Washington-Pagano
6. Sarpi
7. B. Aires-XXII Marzo
8. Ticinese

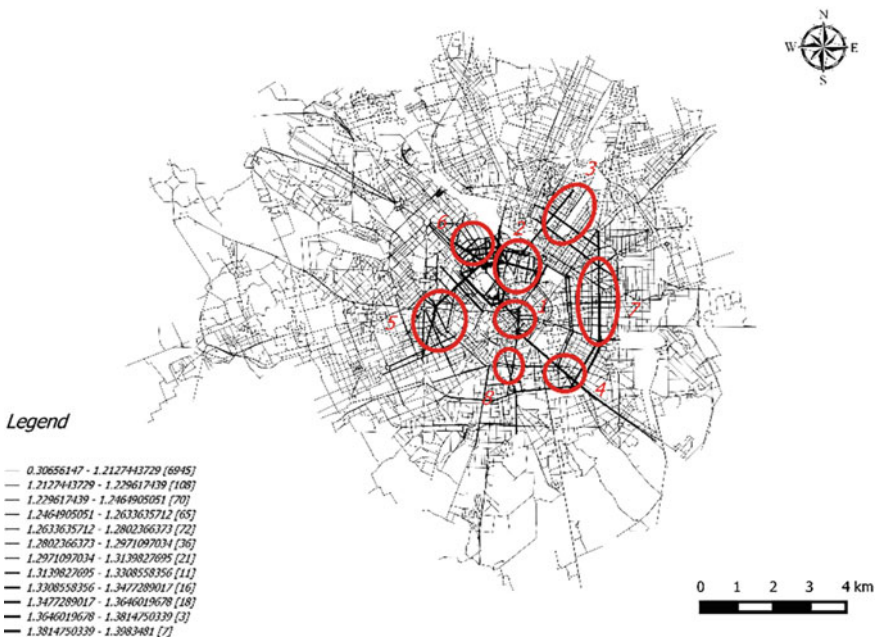


Fig. 3 Integration cores of Milan at 2014

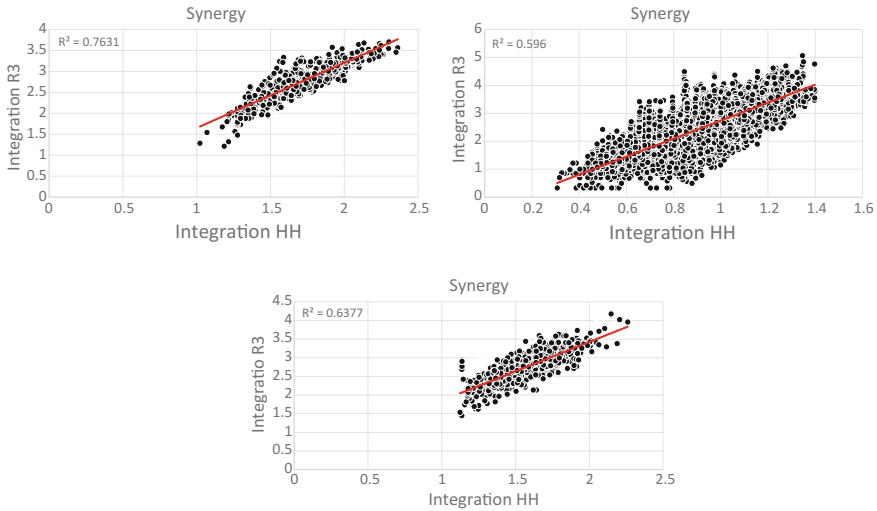


Fig. 4 Synergy coefficient of Milan at 1704, 1884, 2014 (from left to right)

The results above incentive to explore a second-level configurational index, the synergy value mentioned above, that is the coefficient R^2 of the correlation between local integration versus the global one. It measures the degree to which the internal structure of an area relates to the larger-scale system in which it is embedded. The figures represent the trend over time of the synergy coefficient, referred to the three maps, showing a progressive weakening. The synergy coefficient of Milan in 1704 is 0.763, what appears suggesting a quite resilient urban settlement, whose labyrinthian configuration provides various alternatives of movement from one site to another. As a consequence of the aspiration of Cesare Beruto to develop a radial structure, several axes gain higher relevance in movement distribution leading to a less flexible urban structure ($R^2 = 0.638$). In the last map, the synergy coefficient decreases as a result of the sprawl of the city of Milan and the growing of the metropolis (Fig. 4).

4 Correspondence to the Reality

In order to face urban issues by means of a configurational approach, it ought first to be verified if Space Syntax is well suited for the city of Milan. In general, since integration is expected to correspond to the actual distribution of retail activities, its value has been compared to the actual activities density, taking a sample of 30 streets, homogenously distributed and provided with a wide range of integration values. The correlation appears positive versus global integration as well as versus local integration (Fig. 5), computed taking account of the lines within a circle of radius 3. In order to filter these outcomes from local factors, the sample has been

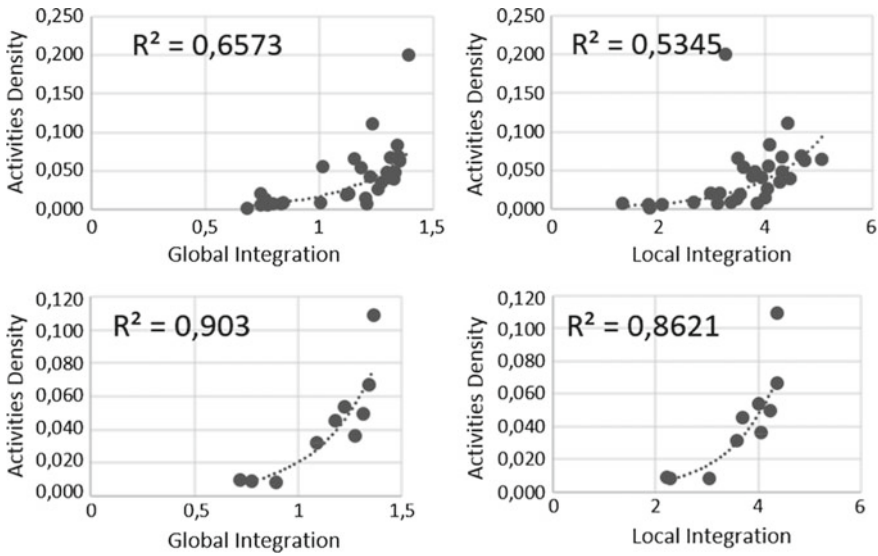


Fig. 5 Correlation between global integration and activities density, in the whole sample (1st row) and dividing the sample into 10 groups (2nd row)

divided into 10 groups of 3 elements. As a result, the correlation, as it is shown in Fig. 5, appears narrow and exponential.

5 Applications: Results and Discussion

The verification results so far briefly presented allows the provision of a positive overall assurance as to the suitability of this approach for the city of Milan; on such basis, the configurational analysis has been used to face several different issues of urban planning, especially referred to different kinds of accessibility. In fact, space syntax is capable to analyse pedestrian, cycle and vehicle movement networks, so as to narrowly reproduce their respective flows.

As the literature, this paper emphasizes the role of integration value as a key factor in the pedestrian movement across the city. The pedestrian movement is the mobility model that has the capacity of maintaining the most direct relationship and interaction with the city; consequently, there is a necessity of considering the pedestrian accessibility degree within urban settlement. The spatial configuration plays a primitive or principal role for the pedestrian mobility (Hillier et al. 1993) and affects to pedestrians when they have to take the decision about what route they select for their trips. Therefore, the spatial configuration could encourage or discourage the election of a route on which pedestrians can reach their destinations (Handy and Niemeier 1997). This effect on pedestrian mobility is based on the assumption of the

Integration R = 1000 m

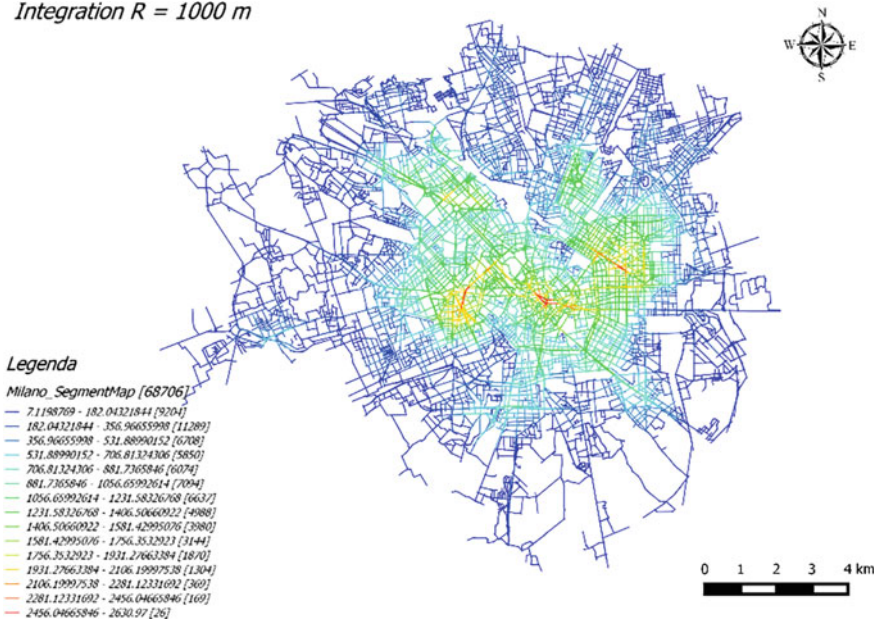


Fig. 6 Integration map of pedestrian accessibility

existence of natural movement, here mentioned above, that is the proportion of urban pedestrian movement determined by the grid configuration (Hillier et al. 1993).

Pedestrian map, shown below, is produced by angular segment analysis based on the radius set to 1000 meters, which corresponds to more or less 13 min, on foot. The pedestrian movement appears mainly concentrated within the central area, where integration cores are indicated to be by space syntax analysis, especially within ‘Centrale’, ‘Duomo’ and ‘Washington-Pagano’ (Fig. 6).

In Fig. 7, the map of cycling accessibility is represented: the accessibility is computed by angular segment analysis and the radius is set to 5000 meters, which corresponds to more or less 30 min by bike (Karlstrom and Mattsson 2009). From the integration map (Fig. 7), it is possible to observe the most accessible areas within a radius of 5000 meters, as well the most frequently visited that can be identified from the choice map (Fig. 8). Using these two maps, the most attractive areas for cyclists can be identified and this information might be useful in a possible decision-making process on localizations of public services aimed at encouraging sustainable mobility.

The third kind of accessibility that was analysed within the city of Milan is the vehicular accessibility. It is computed by axial analysis with radius n, in order to take into account the user’s preference for straight street (axes). Considering space syntax capable to offer the possibility to test different strategic guidelines in urban planning, two diverse applications related to vehicle accessibility are described below.

Integration R = 1000 m

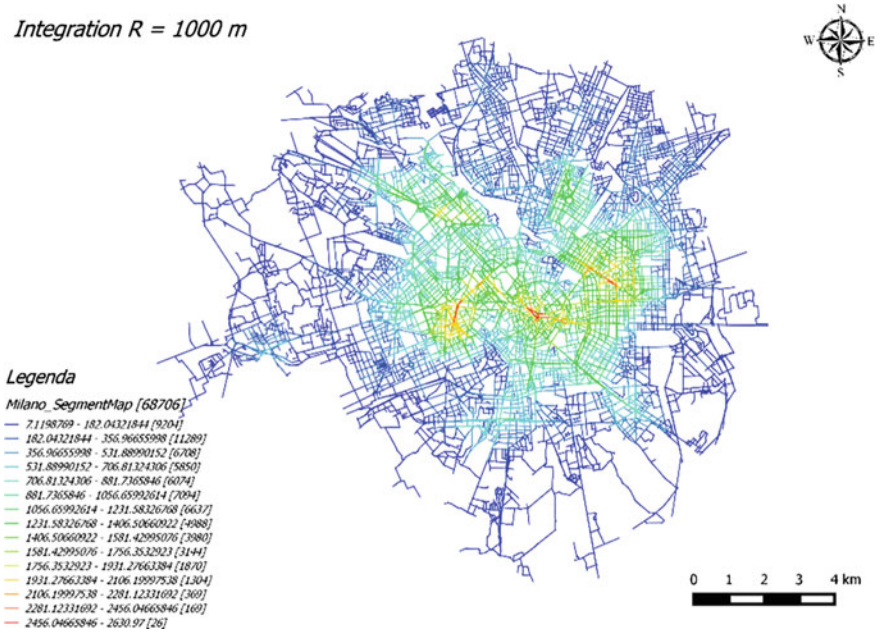


Fig. 7 Integration map of cycling accessibility

Choice R = 5000 m

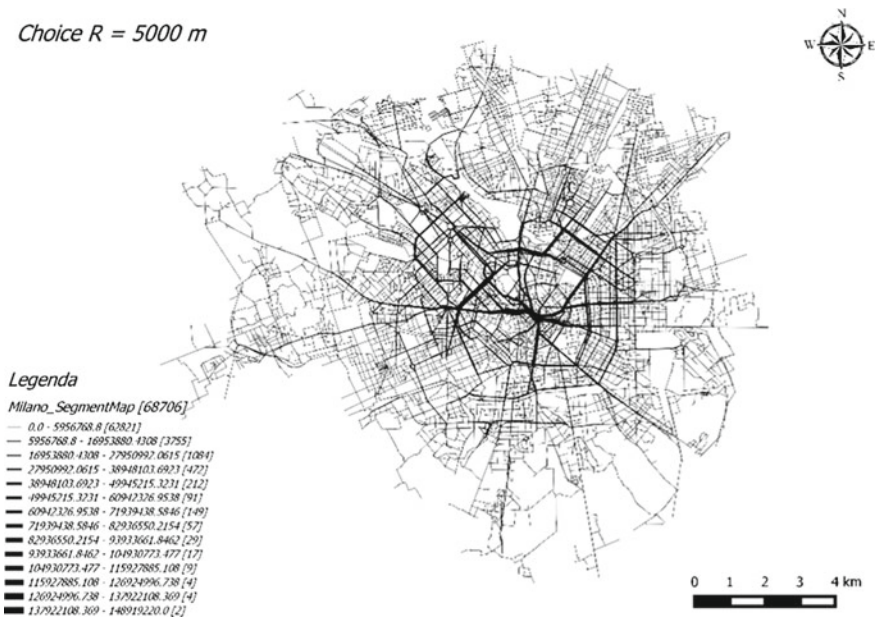


Fig. 8 Choice map of cycling accessibility

The first application consists on using the integration map based on n radius to identify potential car parking localizations: guided by a sustainable planning approach, they are localised along the boundary of the city providing interchange node in order to incentive intermodal transport behaviour. This analysis could result more efficient if integrated with the localizations of the existing park and ride and highlighting zones where they lack (Fig. 9).

The second application regards the study of traffic-restricted zone within the city of Milan, already defined as area C, and encompasses about 8.2 km² and 77,000 residents. The configurational analysis is able to study diverse scenarios of vehicular flow depending on traffic-restricted zone boundary, showing its influence in the distribution of local vehicular traffic flows and highlighting those roads that may assume a diverse role in traffic management. In this case study, the area C is completely close to the motorized vehicles: the main result is that ring road of the city of Milan gains more importance; the integration value along the streets that compose it increases making it more accessible from all the points in the study area.

The approach described has the potentiality to be a suitable planning tool for combining spatial topics and traffic concerns able to define the probable relationships between urban design, derived from the morphologic features of network, and traffic analysis, mainly connected to the distribution of movement flows within the network itself. Moreover, this kind of application can show the influence of traffic-closed zone on the resilience of the city through the study of the synergy coefficient. In this case study, it remains quite the same; that suggests a strong road structure over the medieval walls boundary. In fact, the ring road of the city of Milan assumes a relevance role in traffic distribution even without the closure of the traffic-limited zone as here explored (Fig. 9).

Other useful urban applications of space syntax consist in combining different configurational indicators in order to satisfy specific hypotheses and conditions. An example refers to a scenario for the location of areas for libraries, where two aspects are generally to be assumed as desirable features, if not obligatory requirements:

1. libraries have to be preferably located far from traffic flows, and hence in areas provided with low choice values;
2. libraries have to be easily accessible, and hence located in areas with high values of global integration.
3. These two requirements can be met in two ways:
4. selecting—by a specific query—elements showing both low choice values and high integration values, assuming arbitrary thresholds (Fig. 10);
5. creating a complex index, resulting from choice and integration indicators, suitably weighted (Fig. 10).

This kind of scenario can be implemented into a Geographic Information System (Jiang et al. 1999) so as to integrate the configurational results with the geographic information that indicate the location of the existing libraries in the city, as shown in Fig. 10.

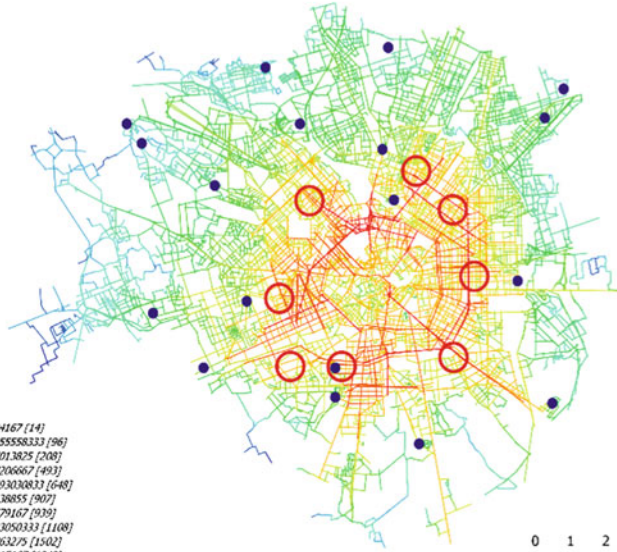
As anticipated above, another relevant and innovative issue in urban planning is the resilience of the urban grid, here regarded in terms of network resilience, as the

Integration

- existing
- proposed

Legend

- 0.30886291 - 0.389409734167 [14]
- 0.399409734167 - 0.48995558333 [96]
- 0.48995558333 - 0.5805013825 [208]
- 0.5805013825 - 0.671047206667 [492]
- 0.671047206667 - 0.76159330833 [648]
- 0.76159330833 - 0.852138855 [907]
- 0.852138855 - 0.942684679167 [939]
- 0.942684679167 - 1.03323050333 [1108]
- 1.03323050333 - 1.1237763275 [1502]
- 1.1237763275 - 1.21432215167 [1048]
- 1.21432215167 - 1.30486797583 [277]
- 1.30486797583 - 1.3954130 [41]



Global Integration

Legend

- 0.30009697 - 0.383786705833 [14]
- 0.383786705833 - 0.466676441667 [82]
- 0.466676441667 - 0.5495661775 [177]
- 0.5495661775 - 0.632455913333 [372]
- 0.632455913333 - 0.715345649167 [643]
- 0.715345649167 - 0.798235385 [734]
- 0.798235385 - 0.881125120833 [1090]
- 0.881125120833 - 0.964014050667 [1124]
- 0.964014050667 - 1.0469039805 [1126]
- 1.0469039805 - 1.129793910833 [837]
- 1.129793910833 - 1.2126838417 [253]
- 1.2126838417 - 1.2955738 [34]



Fig. 9 Integration map of vehicular accessibility and potential location of park and rides (first image); integration map of vehicular accessibility based on prohibited traffic zone (second image)

Localization Libraries

Select by expression:

Choice < 50 % AND

Integration > 90 %



Localization Libraries

● real libraries

○ proposals



$$L = w1 * I + w2 * (1/Ch)$$

Fig. 10 Potential location of libraries within the city of Milan

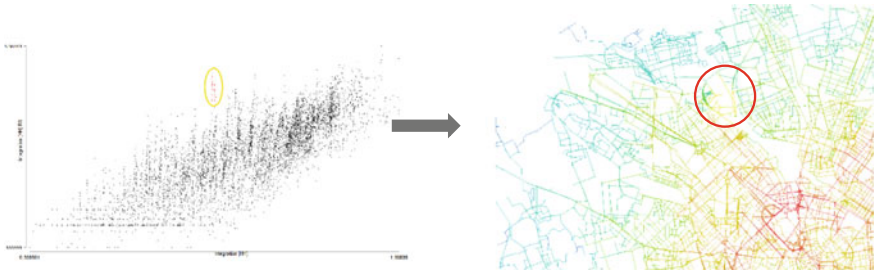


Fig. 11 From synergy scatterplot to integration map

capability of an urban system to absorb changes in their structure without suffering significant variations in its configurational state (Cutini 2013). In order to study the resilience in the case study of Milan, a punctual analysis has been carried out: in the scatterplot of synergy (correlation between global and local integration), a group of dots appears particularly separated from the cloud of the dots of the whole system, as characterized by high values of local integration and (relatively) low values of global integration.

Theoretically, it means that the corresponding streets appear rather segregated from the whole system, and still well integrated in their respective local neighbourhood. The presence of such areas has a negative effect on the global resilience of the city, as it makes the grid more disaggregated. The selected dots correspond to the Bovisa neighbourhood, which is defined as self-supporting quarter in Milan with a specific identity in its urban configuration (Erba et al. 2000). Therefore, this scenario reasserts the capability of space syntax to support the understanding of the inner geography of the city of Milan (Fig. 11).

6 Conclusions

In this study, the configurational analysis is shown as a reliable method, revealing an excellent tool for the diachronic analysis of the system and for the reconstruction of the evolution over time of centralities within the settlement. On the basis of the outcome of the research, space syntax techniques appear well suited for the interpretation of the distribution of activities and centralities within the city of Milan. Moreover, and even more interesting, the results point out the capability of the configurational techniques to support the decision-making process of planning and selecting urban actions and projects, with a particular reference to those involved with the theme of accessibility, usefully supporting the present and future location of public spaces. Furthermore, the results show that such kind of approach actually enhances the transparency of strategic decisions concerning the design and planning of urban spaces, making to emerge and highlighting their likely effects on a wide range of aspects and phenomena.

Possible future developments are plenty, such as adding some other historical dates that correspond to relevant urban transformations of the city; or, considering other socio-economic variables to be compared with the integration value, such as the distribution of social network (such as Facebook or Twitter) flows or the distribution of traffic flows over the whole map. Furthermore, it would be possible and interest to determine and discuss other—secondary—indices, resulting from the aggregation of two or more configurational parameters in order to point out other specific features of the system.

Acknowledgements This research is an outcome of a team cooperation between the all three authors. In particular, Farese has conducted the operative and computational part of this research; the analysis and the interpretation of the outcomes has been got by the collaboration between Cutini and Farese.

References

- Cutini V (2001) Centrality and land use: three case studies on the configurational hypothesis. *Cybergeo, Rev Eur Geogr* 188
- Cutini V (2013) The city when it trembles. Earthquake destructions, post-earthquake reconstruction and grid configuration. In: Kim YO, Park HT, Seo KW (eds.) *Proceedings of the 9th international space syntax symposium*, Sejong University, Seoul, pp 102.1–102.17
- Erba V, Molon M, Morandi C (2000) Bovisa una riqualificazione possibile. Unicopli, Milano
- Handy SL, Niemeier DA (1997) Measuring accessibility: an exploration of issues and alternatives. *Environ Plann A* 29(7):1175–1194
- Hillier B (1996) *Space is the machine. A configurational theory of architecture*. Cambridge University Press, Cambridge
- Hillier B, Iida S (2005) Network effects and psychological effects: a theory of urban movement. In: *International conference on spatial information theory. COSIT, 2005: Spatial Information Theory*, pp 475–490
- Hillier B, Penn A, Hanson J, Grajewski A, Xu J (1993) Natural movement: or configuration and attraction in urban pedestrian movement. *Environ Plann B: Plann Des* 20:29–66
- Jiang B, Claramunt B, Batty M (1999) Geometric accessibility and geographic information: extending desktop GIS to space syntax. *Comput Environ Urban Syst* 23:127–146
- Karlstrom A, Mattsson LG (2009) Place, space syntax and attraction-accessibility. In: Koch D, Marcus L, Steen J (eds.) *Proceedings of the 7th international space syntax symposium*, Royal Institute of Technology, Stockholm
- Oliva F (2002) *L'urbanistica di Milano: quel che resta dei piani urbanistici nella crescita e nella trasformazione della città*. Hoepli, Milano, pp 420–430
- Turner A (2007) From axial to road-centre lines: a new representation for space syntax and a new model of route choice for transport network analysis. *Environ Plann B: Plann Des* 34:539–555