# Configuration and resilience: some remarks from the cases of Florence and Milan

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## Keywords

Resilience, spatial analysis, configurational approach, Florence, Milan.

## Introduction

In the last years the theme of urban resilience has been increasingly regarded as a key property of urban systems for two main reasons. The first one is the growing awareness and public concern of the threats deriving from disastrous events, which appear having become more frequent, as a result, according to some, of the effects of climate change; but also man-made hazards, such as those related to mass events, war and terrorism, are increasingly feared in the common sensitivity. The second reason is more general and not so recent: the slowdown in the demographic growth of most European cities in the last decades of the twentieth century has caused the main focus of the debate to shift onto the inner transformation of urban settlements, especially related to the crisis of the industrial city and advent of the post-industrial society. And, when it goes at transforming

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the social and functional state of the cities, the issue of the capability of their spatial features to adapt to change assumes a vital importance.

The present research will assume a relational notion of resilience, regarding it as depending on the relationships connecting each element of the observed spatial system to all the others; this assumption allows analysing its measure and diachronic transformation by means of a configurational approach, using the space syntax techniques, which in the last decades have been widely demonstrated to be a reliable tool for the analysis of spatial systems. Space syntax - as a theory and a complex of operational techniques - was first introduced in the late 70s by Bill Hillier; since then, it has been the subject of an amount of studies, developed by a wide community of researchers all over the world. Two main assumptions are recognized at the basis of this approach: one is the role the urban grid, assumed as the primary element of the phenomena that occur along its paths; the other consists in assuming that each spatial element of the grid is provided with an own configurational value, which does not depend on its geometric or morphologic properties, but merely on the relationships between it and all the others in the grid. On such basis, each spatial element is provided with a full set of parameters, suitable for describing its configurational value. Among them, the most commonly used are connectivity, integration and choice.

Connectivity value (corresponding to grade in graph theory) is the number of direct connections of a spatial element. Integration value (corresponding to closeness in graph theory) is defined as the mean depth of a spatial element with respect to all the others (Hillier, Hanson, 1984), so as to reproduce its accessibility: that is how easy is it to get to (and from) all the other elements. Concretely, in fact, the integration value was proved suitable for narrowly reproducing the actual density of the located activities: the

integration value appears to correspond to the distribution of attractiveness, thus suggesting the vocation of a place to work as an appealing location (Cutini, 2005). Choice value (corresponding to betweenness in graph theory), defined as the frequency of a spatial element on the shortest paths connecting all pairs of other elements, is suitable for measuring how likely a spatial element is to be passed through: in fact, several studies attest a narrow correlation of choice with the distribution of movement flows (Hillier et al., 1983; Penn et al. 1998; Hillier, Iida, 2005). In other words, all those parameters can be assumed as indicators of urban centrality: while connectivity indicates the role of a spatial element as a local pivot of connections, integration reproduces the to-movement potential of a spatial element as a route destination, and choice measures the through-movement potential of an element as a piece of route.
This research will hence use a configurational approach in order to analyse the resilience of Florence and Milan, two of the most prominent urban settlements in Italy; they appear ideal case studies as regards the matter here discussed, due to their relevance and the several changes they have undergone over the last two centuries.

## Backgrounds

In recent years, the theme of resilience has been declined under several different meanings, so as to indicate features that significantly differ from each other: the capability of a city to take a perturbation, retaining the efficiency of its plants and infrastructures (Jha et al., 2013), or to maintain its social wholeness and cohesiveness (Paton, Johnston, 2006; Pelling, 2003); appraised as a spatial feature, depending on the geometry and configuration of the street network, the theme of resilience was addressed discussing the role of the urban grid on vulnerability in case of disasters (Gil, Steinbach, 2008; Muhareb, 2009; Muhareb, 2011), as well as the possible use of configurational indices to reproduce the level of resilience with reference to the seismic risk (Sarı, Kubat, 2011). These studies actually focus on resilience as a matter of performance of the street network in the immediate post-perturbation phase, with reference to the question of accessibility and evacuation.

Despite the crucial interest of all the issues above, which won't be debated in the following, the notion of resilience here assumed and discussed is quite different: it regards the spatial features that can assure an urban settlement the capability of sustaining disruptions and local alterations of the spatial grid with limited changes on its global behaviour and the phenomena that occur within its paths.

In order to discuss such notion of resilience, three main configurational indices will be investigated; they have been so far introduced and tested (Cutini, 2013) and can be suitably applied to the case studies of Florence and Milan.

A first parameter is the mean connectivity value of the whole urban grid, which appears a basic clue of the density and variety of paths connecting each line to all the others of the axial map: low values of connectivity will stand for the frequent presence of obliged paths, while on the contrary high mean values, should any path get interrupted, are likely to guarantee the richness of alternative routes. Its value obviously varies from 2 to n, thus reproducing the capability of the urban system to adapt its movement pattern to different spatial layouts, as a consequence of changes in its grid (Cutini, Rabino, 2012). Another index of relational resilience derives from considering resilient the systems that are provided with a widespread presence of shortest paths all over the grid; on the contrary, the systems that are characterized by their dense concentration through a smaller number of spatial elements are to be regarded as more vulnerable: in this respect, an indicator of resilience is the ratio of the highest choice value and its theoretical maximum value, occurring if all the shortest paths in the grid should share a spatial element. If we consider an axial map of n lines, this index, to be called frequency index, can be determined as follows:

$$v = choice_{max}/(n^2/2 - 3/2\ n + 1)$$

The frequency value obviously varies from 0 to 1, increasing as the resilience of the system decreases. Should an element be located on all the shortest paths connecting all the couples of others (v = 1), the system would result vulnerable to its highest degree, in that each route would depend on that single element: should it get affected by any perturbation, the whole system would evidently collapse.
A further index of network resilience comes from considering the resilience as depending on the capacity of the whole system to take and adsorb local perturbations: the $R^2$ coefficient of the correlation between global and local (R = 3) integration, called 'synergy coefficient' can be assumed as a clue of steadiness of the system, in that reproduces the strength of the correlation at different scales: the anchorage of a local area to the global pattern of the system in fact is expected to enhance its stability, thus reducing its vulnerability in front of a perturbation. Those three parameters can hence be used as indicators of the network resilience of the system, and, when observed at different subsequent dates, their changes can usefully reproduce its trend over time: what is precisely the purpose of the present research. The diachronic analysis of the grid configuration of Florence and Milan at different dates will allow determining the variations of those indices over the decades, so as to reconstruct the trend of urban resilience in the

observed case study, from the last pre-industrial era up to the present time.

## The case of Florence

In order to conduct a diachronic analysis of Florence, nine significant dates have been selected, suitable for identifying as many epoch-making moments in the modern growth of Florence. The first one is 1825, date of the Lorraine cadastral registry, which reproduces in detail the consistency of the city in 1:1,250 scale, thus registering its state just before the beginning of the modern urban growth. The second date is 1858, just the year before the end of the Lorraine period and the subsequent annexation to the Reign of Italy, when the layout provides evidence of the first changes of modern times, such as the urban developments around the railways stations. The third date is 1867, which represents the 6 years of Florence capital of Italy, and, above all, reproduces all the transformation works carried out for such role. The fourth and fifth date are 1910 and 1938, witness moments of the progressive consolidation of the radial growth out of the inner core. The sixth date is 1955, reproducing the saturation of the flatland towards south and east, and the beginning of the unidirectional growth towards north-west; the conclusion of this growth is attested by the cartography at the eighth and ninth dates, respectively 1990 and 2015, with the progressive merging of the north-western urbanization with the pre-existing urban settlements and the making of the present conurbation. The grid corresponding to each of the dates above was analysed by axial analysis. As utterly representative of the diachronic dynamics of Florence, the four dates of 1825, 1910, 1955 and 2015 are here selected in order to depict in figure 1 the distribution of integration value all over the grid of the settlement.

For a better comprehension, different scales of representation are here used, in order to maintain a full view on the whole system and clearly describe the distribution of values and their trend over time.
Some evidence emerges from the observation of those results. First, a progressive shifting of centrality, from the geometric centre of the inner core towards the external radial developments, is clearly shown in figure 1: while in

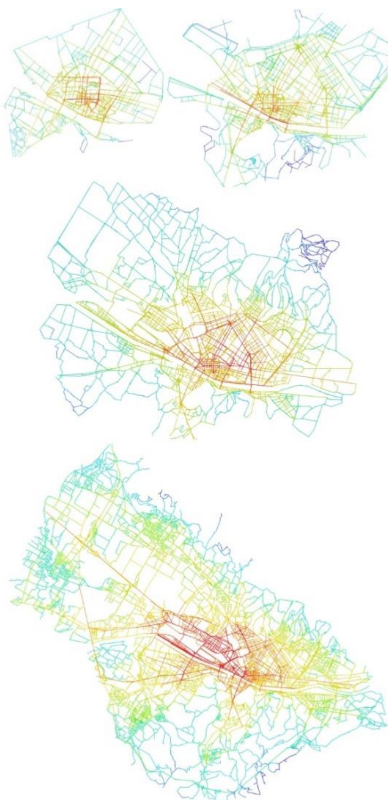

Figure 1 - The distribution of integration value in the grid of Florence at 1825 (top, left), 1910 (top, right), 1955 (middle) and 2015 (bottom)

the first map of the XIX century the main integrators appear to steadily persist
coinciding with the cardus and decumanus of the original Roman layout of the city, in the very heart of Florence, since the early twentieth century the outer ring appears gaining more and more attractiveness. The making of the conurbation, in the last decades of the century, appears to involve the clear orientation of the integration core towards north, up to the last state, at 2015, showing it steadily anchored between the ancient townwalls and the recent northern developments (figure 1, bottom right). Still, some further results, even more significant, appears from the observation of the resilience parameters so far described. The mean connectivity value, well over 16 in the nineteenth century, gradually decline in the last century, so as to arrive to 8 at the present state; the synergy value appears following a similar pattern, declining from 0.92 to 0.55, thus demonstrating a gradual weakening of the correlation between global and local integration; and the third parameter too actually seems in line with the others, increasing in the same period from 0.13 to the present 0.27. All those values are here summarized in table 1.

Table 1 - The trend over time of the resilience indices in the grid of Florence at 1825, 1910, 1955 and 2015

| | 1825 | 1910 | 1955 | 2015 |
|---|---|---|---|---|
| *mean connectivity* | 16,39 | 13,26 | 9,18 | 8,23 |
| *synergy index* | 0,92 | 0,87 | 0,78 | 0,55 |
| *frequency index* | 0,13 | 0,13 | 0,16 | 0,27 |

It is worth noticing that the trend over time of the observed parameters appears similar, and actually consistent with a progressive decrease of resilience. The richness (or, better, the redundancy) in the connections between spatial elements, in fact, dramatically decreases, as well as the correspondence of the local configurational pattern, referred to that of the single neighbourhoods, with the global one declines in the last decades. At the same time, there is a simultaneous gradual increase of the polarization of movement flows, which in 1825 appear diffusely scattered all over the grid and today are concentrated on a limited number of spatial elements. Besides, the resilience of the whole system appears weakening as a result of the recent growing of the conurbation and to the strong polarization of the network structure around a limited number of road axes, among which the motorway A1, which laps the conurbation on its western side. If, on a one hand, a large amount of internal movement bypasses the urban grid of the conurbation, moving from an urban origin to an urban destination through the motorway, even at the cost of the toll payment, on the other hand the local role of the motorway diverts a significant amount of vehicular traffic flows from the streets of the urban grid, involving the loss of the fertilisation benefit the irrigation of through movement actually provides (Cutini, 2016).

Summing all up, the recent growth of Florence, which has been mainly carried out according to low density values, so as to materialize a diffused and dispersed settlement, seems having involved an alarming rise in the vulnerability of the whole settlement.

## The case of Milan

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 growth of the system over time: 1704, 1884, 2014. The first map is a representation of the city of Milan by Daniel Stoopendaal, at the time of the Austrian domination. The urban setting is similar to that of the 17$^{th}$ century and will remain unchanged until the end of the century. In this period, the city of Milan is devoid of technical planning support; yet, the realization of the land register is under the will of the Habsburg sovereigns. In this map, the Duomo appears complete in its layout and all the main churches are identified. The second map shows Cesare Beruto's town plan in 1884. This plan responds to the expansion requirement suggesting a radial reticular system that forms blocks of about 200-400 meters per each side in order to allow large residential or industrial buildings. The new road network provides a characterization of roads according to their respective importance; the urban design resulting from this town plan consists of radial axes converging towards the centre and circular rings. The last map of the diachronic analysis represents the city of Milan nowadays. The town plan is a flexible plan that can be modelled on the real effects it produces. The most important difference from the previous maps is that a new model of spatial organization of the city is here affirmed: a new urban-reticular-multicentre configuration, as an alternative to the radial-monocentric, is planned to overcome the habit of progressive consumption of uninhabited soil and to provide mix functional approach.

Ever map has been digitalized and analyzed by space syntax; as in the case of Florence, it was preferred to use different

scales of representation, so as to provide a clearer overall view of the system.
Interesting outputs come from the observation of integration core, in that it allows to determine the evolution of urban centralities over time (Cutini, 2001). Centrality is a key factor in shaping both urban space and urban life; the integration core, suitable for reflecting 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 appears linear and developed within adjacent and central streets where historically commercial activities were concentrated. The urban expansion in the late 1800s led to an outward shifting of the centrality due to the first urbanization beyond 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. The findings of this spatial analysis reflect the aspiration and spatial strategy of Cesare Beruto - expressed and materialized 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 relevant changes in terms of urban development, population growth and industrial progress, gaining an area of about 182 kilometres. The main feature 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, several centralities turn out in the last one.

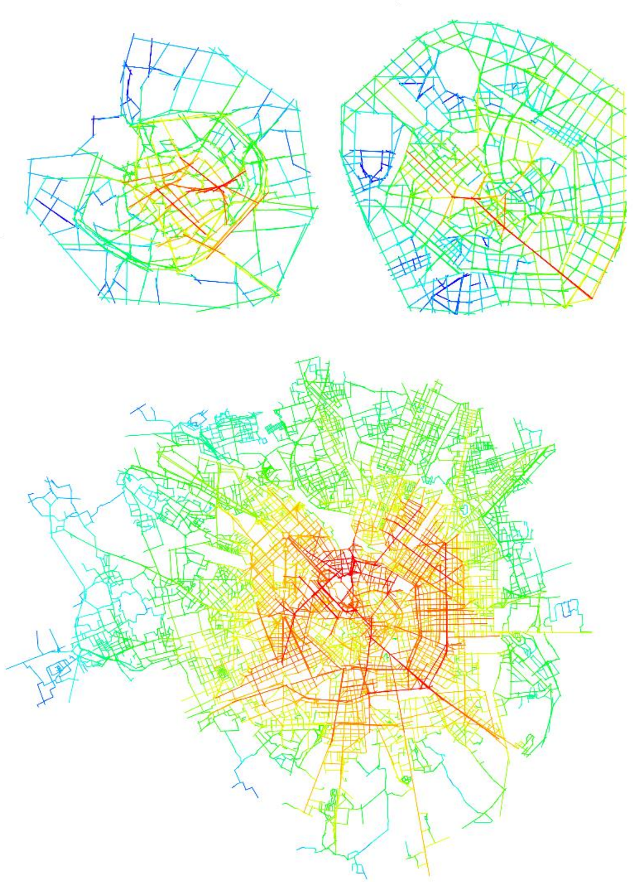

Figure 2 - The distribution of integration value in the grid of Milan at 1704 (top, left), 1884 (top, right), 2014 (bottom)

As the case of Florence, the analysis of Milan reveals interesting results from the observation of the resilience parameters. The mean connectivity value of the whole urban grid decreases from 9.91 in $18^{th}$ century to 8.69 in 2014, indicating a slightly higher presence of interrupted paths within the road network. The synergy coefficient of Milan in 1704 is 0.763, what appears testifying a rather 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 slightly decreases as a result of the growth of the city of Milan and the making of the metropolis. Moreover, the frequency index seems to match the output of the other indices; it increases from 0.21 in 1704 to 0.35 in 2014 so as to attest the decrease in the resilience of the city. All these values are summarized in the table below.

Table 2: The trend over time of the resilience indices in the grid of Milan at 1704, 1884, 2014

| | 1704 | 1884 | 2014 |
|---|---|---|---|
| *mean connectivity* | 9,91 | 8,90 | 8,69 |
| *synergy index* | 0,76 | 0,64 | 0,60 |
| *frequency index* | 0,21 | 0,23 | 0,35 |

Taking into account all the three indices, it can be stated that the three resilience parameters appear to describe the same trend over time, showing a slight reduction of the resilience of the system. This decrease is due to the urban growth of the city of Milan, whose pattern involves a higher vulnerability of the system in case of a perturbation.

## Results and conclusions

In this study, both cities have been analysed by a configurational approach in order to highlight how the hierarchical pattern of the streets and the resilience of the whole network have changed over time.
Several differences obviously distinguish the observed case studies, whose configurational indices actually don't allow a strict comparison. Apart from the size, also the structure of the settlements appears characterized by relevant different elements: Florence presents a quite regular grid within the ancient nucleus, while the external development due to the urban growth over time did not follow a precise and regular pattern. Differently, Milan is characterized by three main ring structures around the city that have generated something like a concentric structure; moreover, different types of street-network densities are within each ring road, some of which have a regular pattern and some not.
For what concerns the output of the analysis, the distribution of integration values within the network provides some constants elements, as in both cases we may observe a clear outward shifting of centrality, from the original nucleus towards the external areas. At the same time, a significant difference arises, since in Milan the growth over time has involved the making of a multicentre configurational development, with an isotropic diffusion of centrality that has interested the whole circular belt around the inner core; the urban expansion of Florence, on the contrary, has clearly determined a unidirectional shifting of centrality towards the northwest external areas, with a noticeable impoverishment of the appeal of its historic nucleus.
Also the trend of resilience shows similarities while suggesting some significant differences. In both cases all the three indices describe a negative trend of resilience over

time; nonetheless, in Florence the decrease over time of mean connectivity and synergy - as well as the increase of frequency - results much more dramatic than in Milan, so as to attest that the recent development of the Tuscan city has determined a radical worsening of the vulnerability of the system. Such finding can be put into a relation with the respective modality of growth, which in Florence was mainly characterized by low density values and the presence of interstitial areas scattered all over the settlement, a phenomenon that is generally described as leapfrogging urbanization. Such finding, aside from this case study, appears hence to confirm that sprawl, commonly identified by low density urban growth with leapfrogging urbanization, is in itself a likely cause of urban vulnerability, strongly concurring in the decrease in resilience of the settlement.

**Acknowledgements**

This research is an outcome of a team cooperation between all the three authors. In particular, the methodology is the result of the discussion of Valerio Cutini and Giovanni Rabino; Valerio Cutini analysed the case of Florence; Denise Farese analysed the case of Milan; the comparison and discussion of the outcomes has got by the collaboration between Valerio Cutini and Giovanni Farese.

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