11 Multiple centrality assessment: mapping centrality in networks of urban spaces

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Introduction

Centrality is a key factor in shaping both urban space and urban life. Places that are *perceived* as central in respect to all others in the system of reference are assigned more value, are easier to reach and are more clearly conceptualized. Apart from such *cognitive* prominence (Conroy-Dalton and Zimring, 2003), places can be actually *located* in a more central position in the system of city spaces: in this case, they exhibit a *geographic* prominence. The two dimensions of centrality of a place, cognitive and geographic, are strictly interwoven in a complex dance, a subtle balance which plays a crucial role in contributing to the performance of that place in terms of many relevant urban dynamics.

Central places tend to be more *popular*, in that everyone knows where they are located and can drive you there with simple, straightforward directions; they also are more popular in the sense that they are very often crowded with people moving around for a lot of different reasons and taking advantage of the environmental and human diversity. Because of that, central places are usually *safer from criminality* because they are more efficiently self-surveilled (Newman 1973): more people on the street means more eyes on it (Jacobs 1961), more social control and more informal collective management of problematic situations, cases and needs. Also, central places are *richer in secondary activities and services* of all kinds that exist in the daily, ordinary exchange with other people in movement: grocers, pharmacies, libraries, wine-bars and cafés, butchers and greengrocers, music and clothes stores and the like, which in turn attract more and more people to a public space which makes it safer and safer again. In turn, this favours the introduction of *other primary land uses* like theatres, opera houses, city halls, secondary schools and institutions for education and research, major libraries and special activities like civic aquariums, outdoor markets and exhibition centres. Primary activities in turn attract other people again, which further reinforces the virtual loop towards the making of a lively, vibrant, diverse, popular and safe urban centre.

Why was multiple centrality assessment created?

Because the creation of such urban centres is a priority for any policy of sustainable urban planning and design aimed at the realization of the nodal/information city of the future (Newman and Kenworthy 1999), whatever may help in understanding the potential of an existing place to be central, as well as that of a proposed place in alternative development designs, is very useful. The lack of the understanding of such potential, in fact, seems to have played a role in the decay and failure of many urban places and projects, especially after the advent of modern planning, such as most – if not all – large social housing estates in the Western world. After previous studies mainly anchored to an interpretation of spatial centrality which was limited to issues of transportation, regional analysis or economic geography (Wilson 2000), and after the 'configurational' approach of space syntax since the early 1980s (Hillier and Hanson 1984; Hillier 1996), multiple centrality assessment (MCA) implements to cities and open spaces concepts and tools of the network analysis of non-spatial systems in sociology (Wasserman and Faust 1994) or the physics of complex networks (Boccaletti *et al.* 2006). The MCA tool produces visually clear, intuitive maps of urban areas and regions, highlighting the centrality of streets in their global or local surroundings (Plate 3).

For what and whom was MCA created?

In any effort towards the sustainable city of the future it is important to understand which places hold the greater potential to be, or become, the 'backbone' of a neighbourhood, a district or a city. Much of the recent debate about urban sustainability at the international level, in fact, focuses the concept of compact, walkable, diverse urban centres (Jenks and Dempsey 2005) as the anchors (or 'nodes') of a metropolitan to regional territorial framework that minimizes the need of cars and private transportation while maximizing the opportunity to choose among a mix of alternative and collective means. Such centres also work as the core of a *hierarchy of community* that embodies a social perspective in a vision of sustainable cities (Frey 1999). Prerequisite to the functioning of such 'transit-oriented' centres (Calthorpe and Fulton, 2001 Cervero 2004) is their capacity to attract people, shops and services at the local level, then upwards in a *hierarchy of mobility* to the district and city levels (Urban Task Force 1999). The locational centrality of streets, as streets are the constituent part of the structure of any urban 'organism' (Marshall 2005), deeply affects this potential, which is also affected by other families of factors, like the 'constitutional' (Hillier 2004) and the functional. Therefore, in short, the *locational*, *constitutional* and *functional* dimensions of a city space contribute to its potential to be the heart of community life at different scales: MCA accounts for the locational, while formal indicators analysis (Porta and Renne 2005) and accessibility analysis to retail and services account for the constitutional and functional.

Altogether, these models may offer a highly descriptive device for the purposes of researchers, students, practitioners, stakeholders and policy-makers in all fields related to urban studies and sustainable development in built-up areas.

How does MCA work?

MCA can be applied to different spatial systems and at different scales, using substantially different procedures. For the purposes of this chapter, we will present the core application that works on networks of streets and intersections: readers can refer to recent publications for any technical and methodological detail (Porta *et al.* 2006a, 2006b, 2006c; Cardillo *et al.* 2006; Crucitti *et al.* 2006a, 2006b; Scellato *et al.* 2006; Scheurer and Porta 2006). The road system is represented as a network of arcs and nodes, which is easily turned into a mathematical device called a graph. The kind of street-graph format that MCA uses is the most common standard worldwide for geographers, traffic planners and everyone in the field of urban analysis: it turns streets into edges and intersections into nodes. Obvious as it might appear, this point should not be taken for granted: in fact, this characteristic differentiates MCA from its closest 'competitor', space syntax, which is based on dual graphs where streets are represented as nodes and intersections as edges. The primal graph ground allows MCA to retain the geographic content of spatial systems, so that distances are computed in metric rather than topologic terms: this property makes MCA more adherent to the traditional urban planning bias in favour of the geographic dimension of space; while space syntax, which is based on topologic distance (number of turns), is more oriented to its cognitive dimension. Thus MCA, by using standard graph representations of road networks, takes advantages of the immense amount of information already available, and permanently updated, in all planning offices of cities in the developed world.

The road graph is then imported into a GIS environment and cleaned up of the many 'rumours' that are always present (in example, invisible disconnections); after the cleaning, a table of connectivity is produced over which the algorithm for the calculation of centralities is launched. Such an algorithm calculates *many different centrality indices* that account for the several different ways in which a place can be considered to be central. This results, again in GIS, in a number of maps where a colour code is applied to streets in order to represent the centrality of those streets in terms of that particular centrality index. Thus MCA does not produce one single 'solution', but instead a set of images which are never identical to each other: urban places can be central in one sense, and at the same time marginal in another sense.

MCA illustrated through an example application

MCA has been applied on many occasions for purposes of research and practice. In partnership with the Agencia de Ecologia Urbana of the city of Barcelona (Spain), MCA has been applied to identify structural properties of the urban network which shed new light on the role of historical routes and patterns that are still at work beneath the surface of the contemporary city (Plate 4). We also are working in Barcelona on a large investigation into the correlation between street centrality and the location of economic activities of all kinds – a huge effort that involves some 170,000 real activities in the metropolitan area.

MCA was also applied with the Agencia in the context of the planning process of the city of Vitoria (Spain), where it helped in defining new visions for the development of the city structure. Under the framework of City Form, a research project led by a consortium of public and private bodies in the UK which involves five universities – Oxford, Sheffield, Leicester, Edinburgh and Glasgow – MCA developed all structural analysis of city-wide and neighbourhood-wide cases: such structural measures were correlated to other sustainability indicators, from environmental to economic, from social to educational, from cultural to institutional. The correlation between street centrality and the location of services and shops is still the subject of an ongoing investigation.

This correlation has already been established through a first case study in Bologna, Italy (Table 11.1). Here the centrality of streets as a result of an in-depth MCA analysis turned out to exhibit a significant correlation with the density of shops and services: such correlation was especially relevant for betweenness centrality, which is a confirmation of the leading role that

Table 11.1 Linear correlation (Pearson index) between kernel density of street centrality and kernel density of ground-floor activities in Bologna: first 15 positions in ranking.

Rank no.	*Correlated variables*		*KDE bandwidth*	*Linear correlation*
	Centralities	*Activites*	*Metres*	*Pearson index*
1	C^B_{Glob}	*Comm + Serv*	300	0.727
2	C^B_{Glob}	*Comm*	300	0.704
3	C^B_{Glob}	*Comm + Serv*	200	0.673
4	C^B_{Glob}	*Comm*	200	0.653
5	C^C_{Glob}	*Comm*	300	0.641
6	C^S_{800}	*Comm + Serv*	300	0.620
7	C^S_{Glob}	*Comm + Serv*	300	0.615
8	C^C_{Glob}	*Comm + Serv*	300	0.608
9	C^C_{Glob}	*Comm + Serv*	200	0.583
10	C^C_{Glob}	*Comm + Serv*	100	0.567
11	C^B_{Glob}	*Comm + Serv*	300	0.565
12	C^B_{Glob}	*Comm*	100	0.555
13	C^C_{Glob}	*Comm*	200	0.547
14	C^S_{Glob}	*Comm + Serv*	200	0.546
15	C^C_{Glob}	*Comm*	300	0.533

the 'passing-through' factor holds in driving the movement economy in a city context.

An application of MCA in an urban design process was developed in Parma, Italy, where the model made it possible to distinguish the potential of open spaces among different project alternatives and finally to identify the best solution for the revitalization of pedestrian paths and green areas (Plate 5).

Notes

1 The *betweenness centrality* (C^B) of a node (intersection) measures the number of shortest paths connecting every couple of nodes in the network that cross that node; therefore, C^B captures the extent to which one space in the city is likely to be passed through while going from each place to each other place.

2 The *closeness centrality* (C^C) of a node measures the overall metric distance that separates that node from every other node in the network; in so doing, C^C captures the simplest notion of a place's spatial centrality as its proximity to all other spaces in the city.

3 The *straightness centrality* (C^S) of a node measures how straight (or linear) is the shortest path that connects that node to every other node in the city, thus giving an idea of the 'searchability' of a place in the cognitive practices for orienteering in the complexity of the city's labyrinth.

4 *All indices can be computed globally or locally*: in this latter case, the local centrality (say: C^C_{1600}) of a node is no more referred to all other nodes in the network, but rather just to those nodes located within a certain distance from it (in this case, 1,600 metres). Local measures give an idea of how centrality changes when changes occur to the geographical territory of reference of the users: for instance, users of ordinary services and activities like grocery stores or corner shops are likely to refer to much narrower portions of the urban area (the neighbourhood) than users of highly specialized functions like large malls, airports, hospitals or financial districts. In this sense, a place which is *locally* central offers potential in terms of the development of urban sub-centres and residential communities.

5 The kernel density estimation is a statistical probability means that visualizes the density of locations of a certain class of features (for example, shops of a certain kind) that are reachable from any point in the city. In this case, the kernel density has been used for correlating features of different categories (basically shops and services on one hand and weighted – by centrality – streets on the other).

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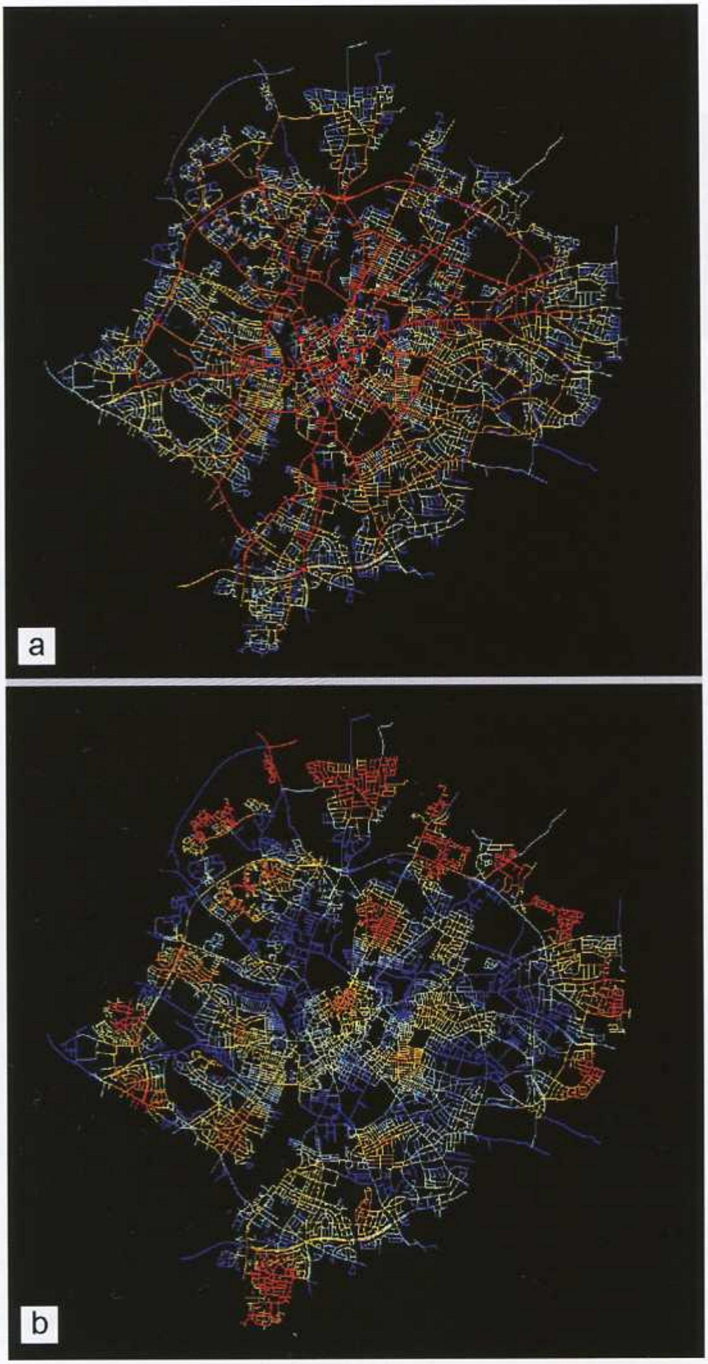

Plate 3 Leicester, UK: mapping global betweenness (a) and local (d=1.600mt) closeness (b). The two indices capture two of the many different hidden hierarchies that are inherent properties of the urban structure always at work together in shaping the cognitive and geographic dimension of our relationship with urban spaces. Application developed within the City Form research framework.

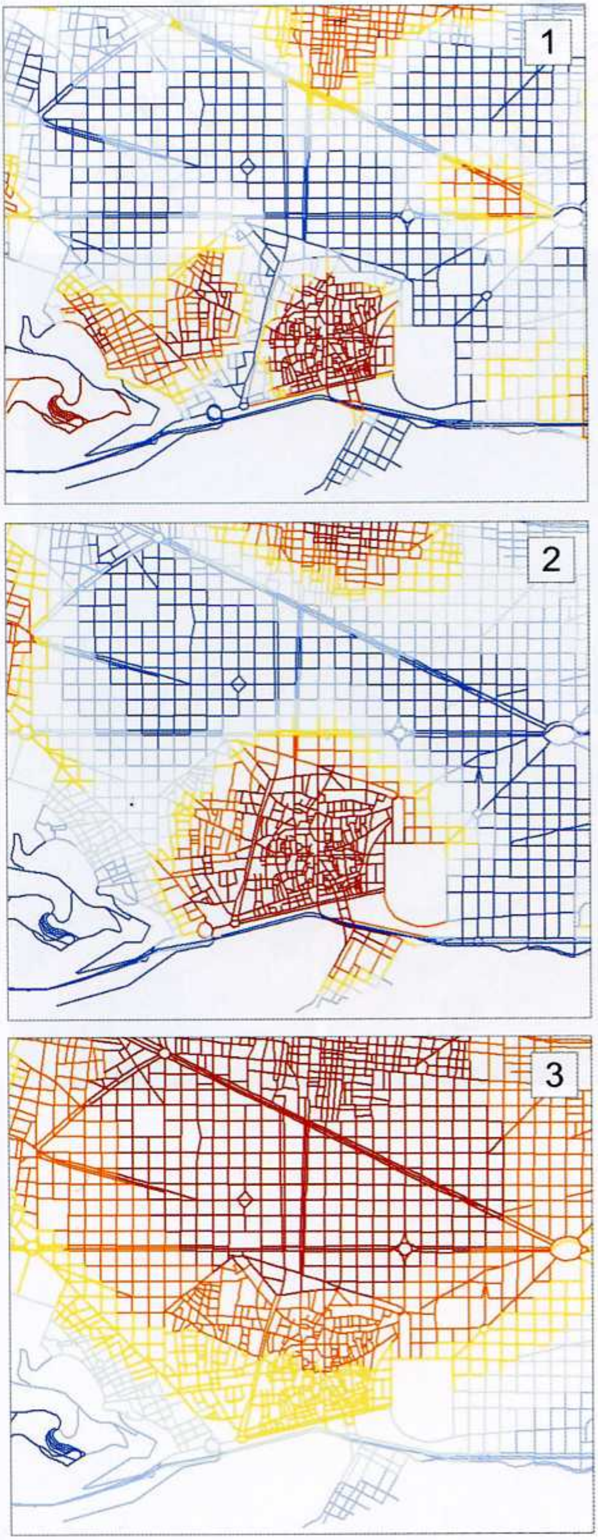

Plate 4 Barcelona, Spain: MCA shows closeness centrality investigated locally (1. d=1.200mt; 2. d=2.400mt) and globally (3). The centrality of contemporary places retains clues of the process of the city's historical evolution: here the Rambla, which lies on the footprint of the ancient city walls, emerges as a 'canyon' of low centrality at the neighbourhood (1) scale, not as a peak as could be expected. It is a peak, actually, at the district (2) and, to a lesser extent, at the global (3) levels. Application developed in partnership with the Agencia de Ecologia Urbana of Barcelona.

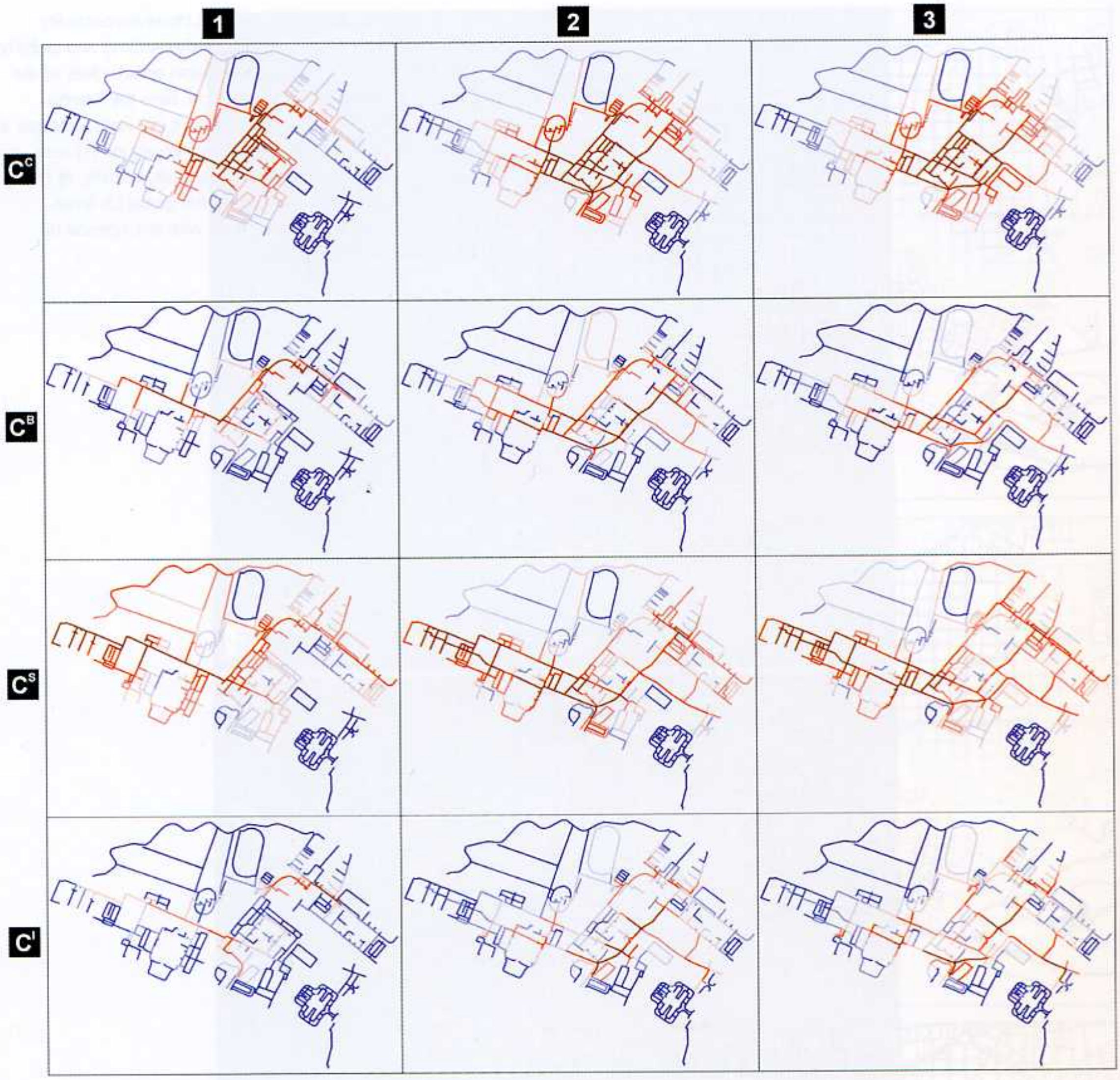

Plate 5 MCA analysis of pedestrian and cycle paths in the university campus of Parma, northern Italy: existing situation (col. 1), first alternative proposal 'the spine' (col. 2) and second alternative proposal 'the ring' (col. 3); centrality: closeness (C^C), betweenness (C^B), straightness (C^S) and information (C^I). The spine solution result was more consistent and was adopted as the basis for the final urban design plan. Application developed in partnership with Rivi Engineering, Italy.