URBAN DESIGN *International* (1999) 4(3&4), 107–127

Centrality as a process: accounting for attraction inequalities in deformed grids

Bill Hillier

Bartlett School of Graduate Studies, University College London, Gower Street, London WC1E 6BT, UK (e-mail: b.hillier@ucl.ac.uk)

The 'centre' of a settlement, whether city, town or village, usually means a concentration and mix of land uses and activities in a prominent location. At any point in time, it is usually fairly clear where the centre is and what its limits are. However, the need to revitalize the centres of towns and cities, has drawn attention to how little we know of the processes by which centres are generated and sustained. Historically, it is clear that centres not only grow and shrink, but also shift and diversify, and with growth to large town or city level, a whole hierarchy of centres and subcentres usually appears diffused throughout the settlement. The challenge is to understand centrality as a process, rather than to describe it as a state. In this paper it is proposed that well-defined spatial factors first play a critical role in the formation and location of centres, and then play an equally critical role in developing and sustaining their vitality. The process works through the impact of spatial configuration on movement, and the subsequent influence this has on land use choices, and the development of the area as an 'attractor' in the settlement layout as a whole. A proper understanding of these spatial factors and the processes they set in train is, it is argued, vital to any programme for the revitalization, sustaining or long-term development of centres.

The problem of centrality

The term 'centre' applied to settlements has functional and spatial elements. Functionally, it means a distinctive concentration and mix of activities in a certain area, spatially a certain position for that area in the settlement as a whole. A functional method for identifying the limits of English town centres, combining GIS analysis of land uses and demography with reviews of informed opinion, has recently been established by Batty and his colleagues (Batty *et al.*, 1998). But what of the spatial aspects? Are the land use aspects independent of space, and the focus and limits of the centre imposed solely by history? Or do they occur in well-defined spatial positions in settlements? Do all functional aspects of centres interact with space in the same way? Or do some require and even generate special local grid conditions, as suggested in the recent studies of Australian and US cities by Siksna (Siksna, 1997)? And what about change? Do centres change solely in response to economic or planning decisions? Or are there underlying spatial processes which tend to push centre development this way or that?

The aim of this paper is to complement the work of Batty's team by outlining a spatial model for the development of a key component of centrality – 'live centrality' – at all levels of settlements. 'Live centrality' means the element of centrality which is led by retail, markets, catering and entertainment, and other activities which benefit unusually from movement. The argument is confined to the live centre because the spatial processes governing live centrality appear to invoke spatial requirements over and above those related to other central functions such as administration, office employment or religion. The key proposal is that a distinctive spatial component is always present in live centres because at all levels it occurs in locations favoured by and influenced by the 'movement economy' process (as outlined in Hillier, 1996a (Chapter 4) and 1996b). The theory of the 'movement economy' was developed from the notion of 'natural movement'

(Hillier *et al.*, 1993) which had arisen from studies showing that, other things being equal, movement flows in different parts of a street network were systematically influenced by the spatial configuration of the network itself. The 'movement economy' theory built on this, and proposed that evolving space organization in settlements first generates movement patterns, which then influence land use choices, and these in turn generate multiplier effects on movement with further feedback on land use choices and the local grid as it adapts itself to more intensive development. It is the movement economy, it is argued, that gives rise to the seamless web of higher and lower intensity areas, including the centre itself as the area of highest intensity, that characterize towns and cities in general.

Spatially, the movement economy process works at two levels in generating a pattern of centrality: a global level and a local level. Globally, the process selects locations which have the appropriate degree of integration with respect to the settlement as a whole. Locally, locations are selected with certain local grid conditions. Both aspects of the process are dynamic. As settlements grow, the pattern of global integration is likely to change, and this will create spatial pressure for a shift in the focus of centrality. An outward shift is the most characteristic manifestion of this. Locally, as centres grow, they create pressure for greater local integration of the kind described by Siksna, that is grid intensification and smaller block size to allow greater ease of movement within the centre. The greater the pressure on the centre, the stronger the 'Siksna process' will be.

A theoretical context to this paper is provided by the debate between configuration and attraction as rival concepts in accounting for urban movement, and the influence movement has on the long-term evolution of the urban surface. In spite of the consistent success of configurational measures in predicting movement, it is clear that in centres at all levels attraction plays an important role in drawing people to the centre. In any urban model that seeks to capture the morphological dynamics of the urban surface, the phenomena to be explained are both the spatial configuration we call the town plan and the pattern of centres and subcentres, or **attraction inequalities**, in the plan. In syntactic terms, the problem is to extend the analysis of configuration to take account of these attraction inequalities in some way.

In this paper a clear answer to this problem is proposed: that configuration generates attraction, at least as far as live centres are concerned, and that the appearance of attraction inequalities in the urban surfaces is to be accounted for by the spatially driven movement economy process. This is not to discount the obvious fact that it is economic and political factors that eventually determine urban development, only that these factors work within the constraints and limits set by the fact that centrality is a spatially-led process.

The phenomena of centrality

At first sight, understanding centrality in towns and cities does not seem to be problematic. Both spatial and functional aspects seem clear and stable: a historic high street or market square as a focus, perhaps, and a concentration of urban functions that have grown up around it to create a central area. Typically, a centre would be marked by a focal 'live centre' of markets and retail, with quieter zones of administration, business and religion in close spatial proximity defining the limits of the central area. All we would need know to understand centrality in such cases would be to identify the focus, describe the limits and map the various functions in their locations.

As soon as we take time into account, however, we find that centrality is often neither clear nor stable, either in its focus or its limits. Although in many settlements the location and limits of the centre do remain more or less in the same place over long periods, in others the centre not only expands or contracts, but may also shift its focus. Most commonly the displacement of the centre is from a historical core towards what was once an edge. Even in quite small settlements this progressive displacement of the centre towards the edge can often be found. For example, in many small hill towns in France and Italy, we find a gradual shift of the 'live centre' from the older, upper parts of the town towards the more active edges lower down, where inter-settlement movement is to be found, perhaps leaving other central functions behind. We can find similar processes even in the most culturally traditional of towns such as Ghardaia and Beni Isguen in the Mzab in Algeria (Salah-Salah, 1987). 'Edge city', it seems, is not a recent state of affairs: it is one of the elementary processes of urban growth (as argued in Hillier, 1996a, Chapter 9: 'The fundamental city').

Centres can also diversify with growth, and the tendency to functional specialization of sub-areas that we find in historic 'centres' can, in larger cities, become spatially distinct centres for different type of function. Both this process, and the edge city process, are evident in London, where the main 'live centre' is in the Oxford Street area – once an 'edge city' – at some distance from both the centre of office employment, which remains in the original historic centre, the City of London, and the centre of administration and religion, which grew up some distance away in Westminster. The formal centre of London is identified not by a concentration of functions in a particular area but by a point south of Trafalgar Square defined between the three main functional 'centres', but lying clearly outside all three.

With enough time and growth the problem of centrality in settlements takes yet another form. In most cities of any size, the problem is not simply to account for a shifting centre or centres, but for a whole 'hieracrchy of centres and subcentres' that pervade the urban structure, ranging from large local centres which can rival or even outstrip the main centre in levels of activity, down to the small groups of shops and other facilities that act as focal points for local areas. Again we are not dealing with a steady state. At all levels of the hierarchy, centres grow and fade, often in response to changing conditions quite remote from the actual centres.

Centrality as a process

Centrality, then, is clearly not simply a state, but a process with both spatial and functional aspects. As a process, it is found to some degree at every level of the urban structure and may, over time, change what once seemed a steady state into a new pattern. It follows that to understand centrality in a way that will be robust enough to guide decisions about the future, we must seek to understand it as a spatio-functional process, not simply as a state, or series of states at particular points in time. The description of states will, of course, be essential to developing knowledge of centrality, but for an effective understanding we must go beyond these descriptions and seek to understand how the changing states of centrality are the products of continuing spatio-functional processes. To attend only to states might be to risk mistaking a momentary state of affairs for a natural state of things. As Batty points out (Batty *et al.*, 1998, p. 22), a preoccupation with states, if linked to policy, could undermine the very spatial dynamics that give rise to the kind of centrality phenomena that we seek to conserve or reanimate.

To understand centrality then we must investigate the relation between its spatial and its functional dynamics, and seek to know how these are driven by the social and economic life of urban societies. Centrality is a special case of our need to understand the relation between structure and function in cities. An understanding of centrality would most likely take the form of a 'structure–function' model capable of showing how spatial and functional dimensions were interrelated, and how both were driven by social and economic activity. Here, it is proposed that the 'movement economy' process is such a model.

First-order diagnostics: syntactic analysis and its limitations

The problem is how should we detect the process in operation. In the absence of time-series data spread over decades or even centuries, we must adopt a more diagnostic approach: to try to identify the process by its products. If the movement economy is the process by which centrality in general is created, then its effects should be detectable in consistent relations between the functional variables by which we mark centrality – land use concentrations and mixes, demographic factors and so on – and distinctive types of spatial patterning. The key questions then become: do we find distinctive types of spatial pattern in functionally defined centres and, if so, what are they? Are they to do with the global settlement form, as the notion of centrality implies. If so, how can this be applied to local centres and sub centres? Or are local grid conditions critical, as implied by Siksna's work? Do different spatial factors perhaps operate at different levels of centrality?

Our first need then is for diagnostic techniques. Let us begin in the obvious place: with orthodox syntactic analysis. Integration analysis, after all, measures something like 'topological centrality' in a line complex at whatever level we choose to set our radius. In London, both global and local integration pick out Oxford Street as the prime integrator, and the West End as the most integrated area. Looking at the radius-3 integration map (the logged version) in Fig. 1, we also find a whole series of long, sometimes wandering routes picked out, mostly but not all radial, and most with significant subcentres along their length.

This is promising, far too incomplete to be anything but a suggestive beginning. There is no identification of where along a line the main concentrations of activity occur, nor of the local extent of these concentrations. More strikingly, the analysis fails altogether to identify certain quite large local subcentres which are not on main routes such as Marylebone High Street (marked **My** on Fig. 1), St John's Wood High Street (Marked **Sj**) and Queensway (marked **Qw**), or more local 'village' centres such as Thornhill Road in Barnsbury (marked **Bb**), Canonbury village (marked **Cn**), or England's Lane (marked **El**). None of the focal lines for these 'centres' are identified as significantly different from others in their neighbourhood.

What is missing? Let us try some more precise diagnositics – or perhaps heuristics would be a better word. Consider first the main north-west radial in Fig. 1, the Edgeware Road, beginning at the top left arrow. Figure 2 extracts its lines from the axial map, together with all lines up to two steps from the lines (the minimum conditions for creating an orthogonal grid) to allow us to examine the changing local grid conditions along the line. Three distinct (and quite large) local live centres lie along its length, each picked out by a dotted ellips: Cricklewood High Street the most northerly marked **a** in Fig. 1, Kilburn High Street in the centre marked b, and finally the section between the Harrow Road and Oxford Street, marked c. Is there any way in which the sections of the road that have become live centres are syntactically distinctive? The answer is clear. Each such section is characterized by a more intensive 'two-step grid' than the non-centre sections of the lines, in the sense that there are larger numbers of smaller blocks close to the line section. This has the simple effect that good numbers of buildings whose entrances face on to the those lines are within the short distance of the live centre line. The local grid conditions, we may say, are distinctive in the live centre parts of the line, and in a way that would seem to maximize local accessibility of dwellings to that line. Preliminary studies of other lines including the Kingsland Road (top right arrow in Fig. 1) suggest similar effects might be found elsewhere.

However, if we look at the 'high streets' and 'village centres' not on main radials (marked with a capital and lower case letter on Fig. 1) we do not find this metrically intensive local pattern. But we do find a local syntactic pattern which has at least some comparable properties. For this, we need a slightly different heuristic technique. Because the 'centres' are not on long radial lines, we construct a local route that passes through the live centre line and look at changing local grid conditions on each section of the route. Figure 3 for example, is such a route for Marylebone High Street. The figure shows the sequence of two-step grids from each line on the route. We see that the live centre line shown top right is distinctive in that it covers the whole of the local grid, whereas others only define a part of it. Figure 4 is a similar sequence for the much smaller-scale live centre line for Barnsbury village, this time ending on the live centre line. Again we see that the local live centre line is distinctive in being the only line that covers the whole system. If we then look at the integration maps of the two areas on their own (cut out from the surrounding grid – Fig. 5), we can see why this is the case. In both cases, the live centre line is the principal integrator in the local system, and in both cases it is because the live centre line is the one that, in effect, joins together local grids which are otherwise relatively distinct. As a result, a more complete local grid can be 'seen' within two steps from the centre line than from any other local line.

Figure 6a then show the two-step grids for four more smaller-scale local centres. The two high streets, St John's Wood High Street and Queensway, both link local grids which are otherwise less well connected to each other. The two 'villages' each define in their own way a well-defined local grid comparable to Barnsbury village. In all four cases, other local lines defined much less complete local grids. Figure 6b then takes another five local live centre lines, inlcuding three with street markets: Whitecross Street, Chalton Street and Columbia Road. In each case, the line is a relatively local line, though usually

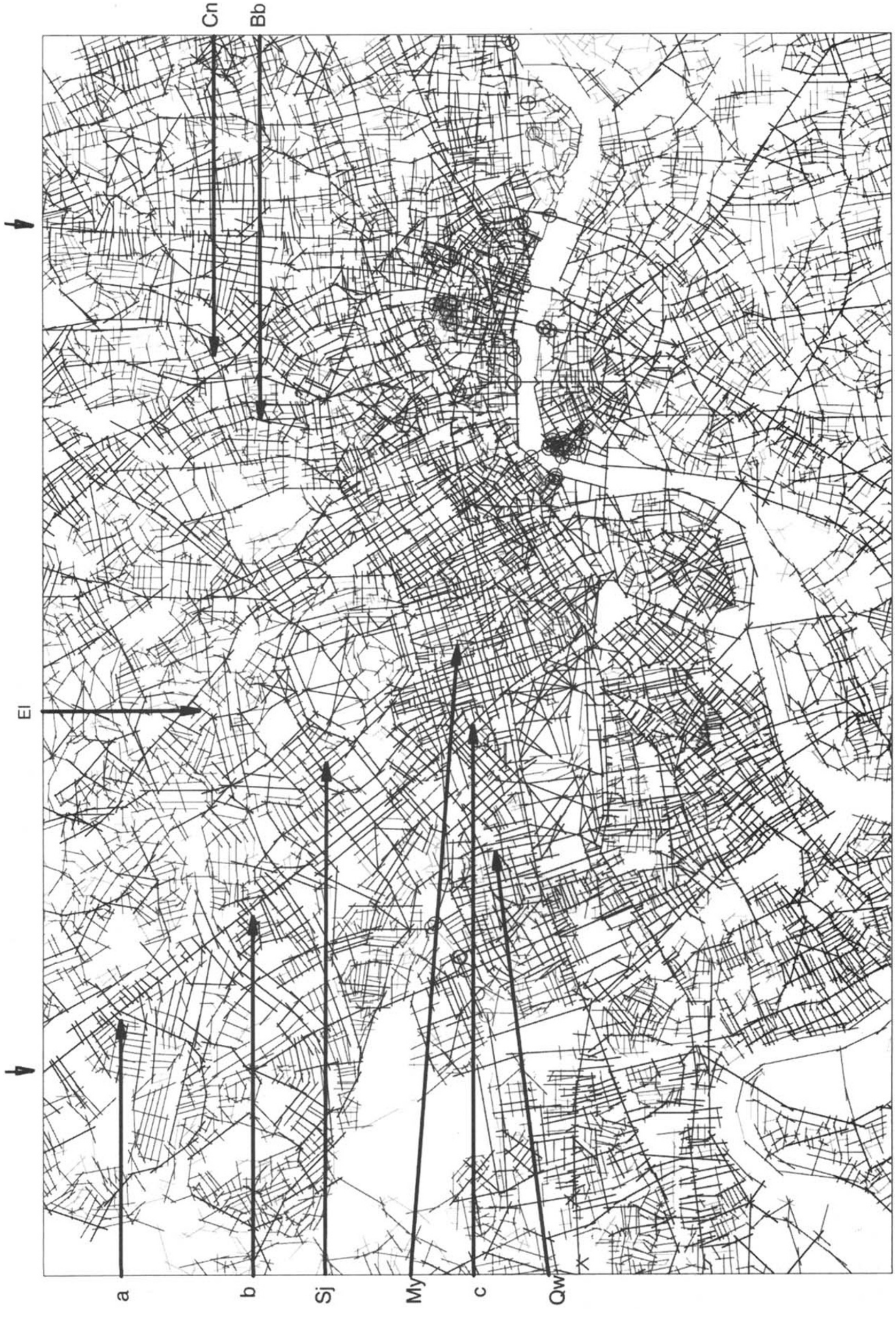

Fig. 1. London – logged version of the radius-3 integration map with integration of lines shown from dark to light.

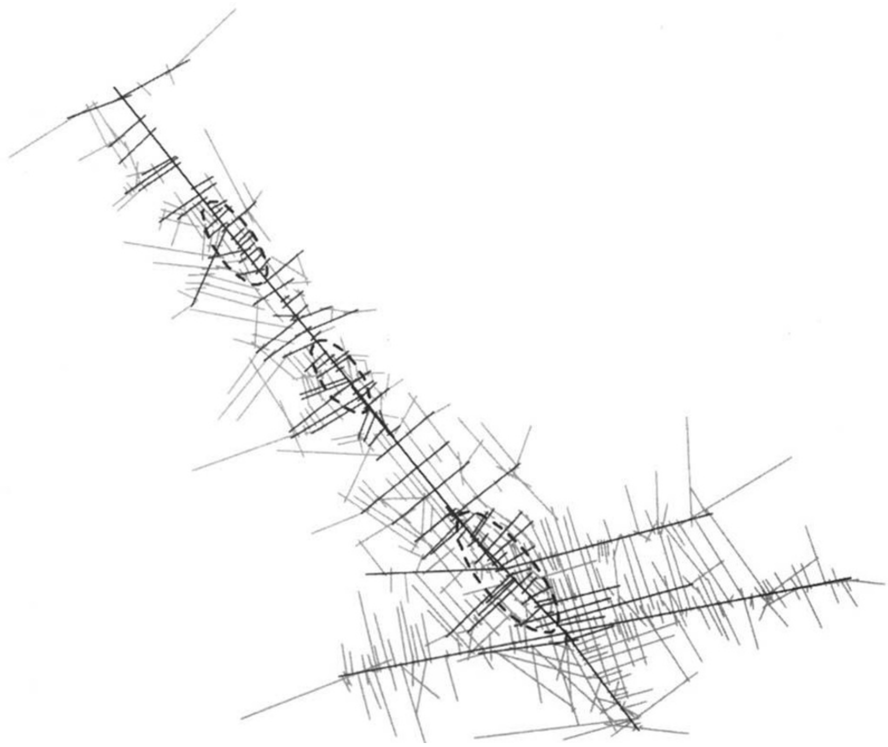

Fig. 2. Edgeware Road (darkest line) plus all lines intersecting it (next darkest) and lines intersecting these (lighter lines).

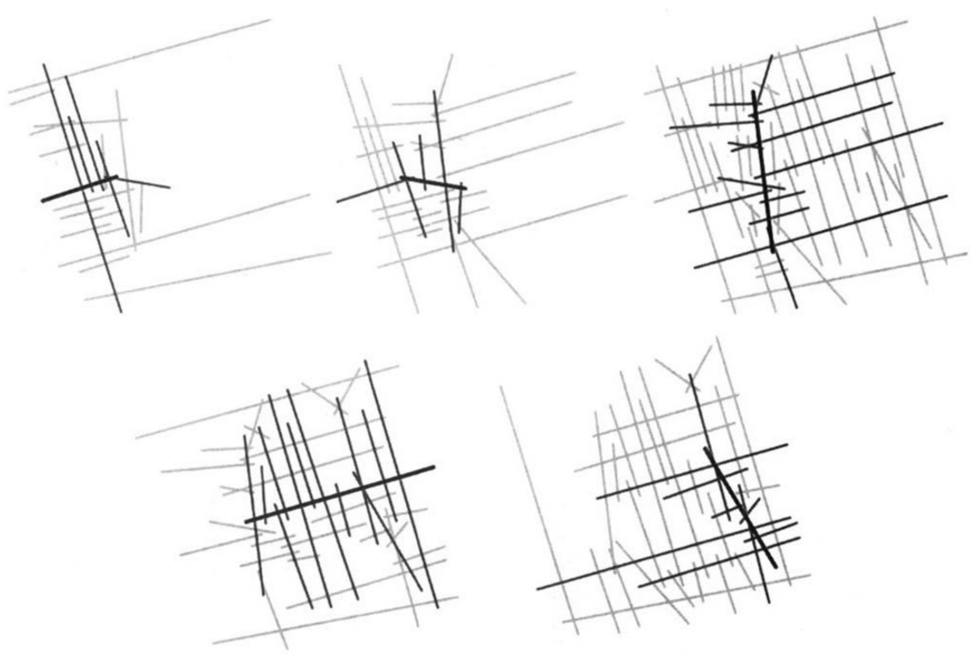

Fig. 3. Marylebone route sequence with the route line darkest, lines intersecting the route are next darkest, and lines intersecting those are lightest. The top right has Marylebone High Street as route.

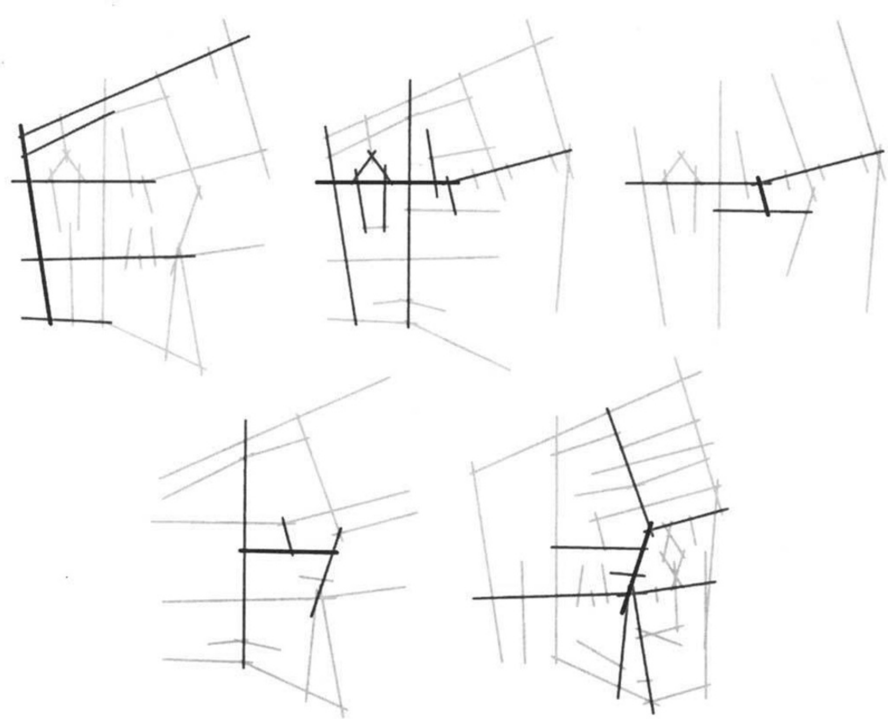

Fig. 4. Barnsbury route sequence, with the routeline as darkest, lines intersecting the route as next darkest, and lines intersecting those are light. The 'village line' is bottom right.

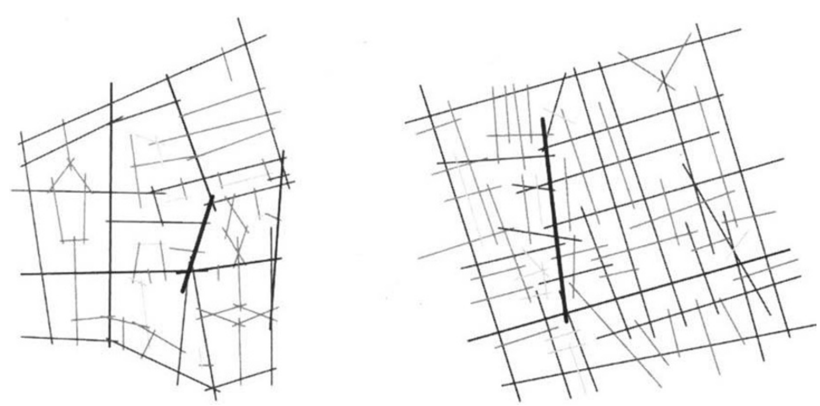

Fig. 5. Marylebone and Barnsbury integration analysis on their own.

linked directly to a more strategically important line in the area (Chalton Street connects to the Euston Road and Crawford Street to Baker Street, while Columbia Road is just off Hackney Road). Each has a strikingly well-defined and more intensive two-step grid than other lines in the vicinity.

We see then that the 'local grid conditions', as shown by the 'two-deep' grid from a line, thus seem to be a distinctive spatial property of live centre lines. Sometimes the two-deep grid describes a more compact and sometimes a looser structure, but the fact that in each case the same two-step definition of local grid conditions does

Fig. 6. (**a**) Two-step grids from selected live centre lines; (**b**) and from further live centre lines.

mark out the local centres as distinctive, albeit with varying metric properties, is suggestive. Now let us try a third heuristic. Figure 7 is an axial map of the north-west part of the Borough of Camden in London with all 1160 current shops (checked through direct observation, because the critical relation is the relation between the shop and the line onto which it opens) and their type located as dots in 49 local centres, varying the scale from minor high streets to single shops. The map was created by Maria Adriana Gebauer-Munoz, a doctoral student at UCL, and a senior lecturer at the Universidad Catolica del Norte in Antofagasta in Chile. Gebauer-Munoz's aim was to ask what, if any, spatial properties could be systematically related to the different scales of the 'centres' shown by the map, measuring the scale simply by the number of shopping, catering and entertainment outlets. Spatial variables were explored at two levels: for the lines on which shops occurred; and for an amended version of the map where lines were added representing the 'shopping segments' of the lines, ending where the shops ended. The spatial variables explored were the various syntactic values of lines and 'shopping segments', the combined syntactic values of pairs of lines segments forming intersections, and various measures of the local grid conditions for the lines and segments. The results were striking. Multiple regression using the main spatial variables produced an r-squared of 0.735 from 10 variables. The best r-squared for a single syntactic variable was 0.286 for integration into local area, the best for intersections was 0.377 for the sum of connectivities of intersection, but the best by far was 0.519 for local integration for segments (Fig. 8) – that is for the integration of the two-deep grid from the 'shopping segment' of the line. Stepwise regression on the spatial variables then showed that local grid conditions, as measured by the local integration value from the segment was the major variable, with a minor role for global

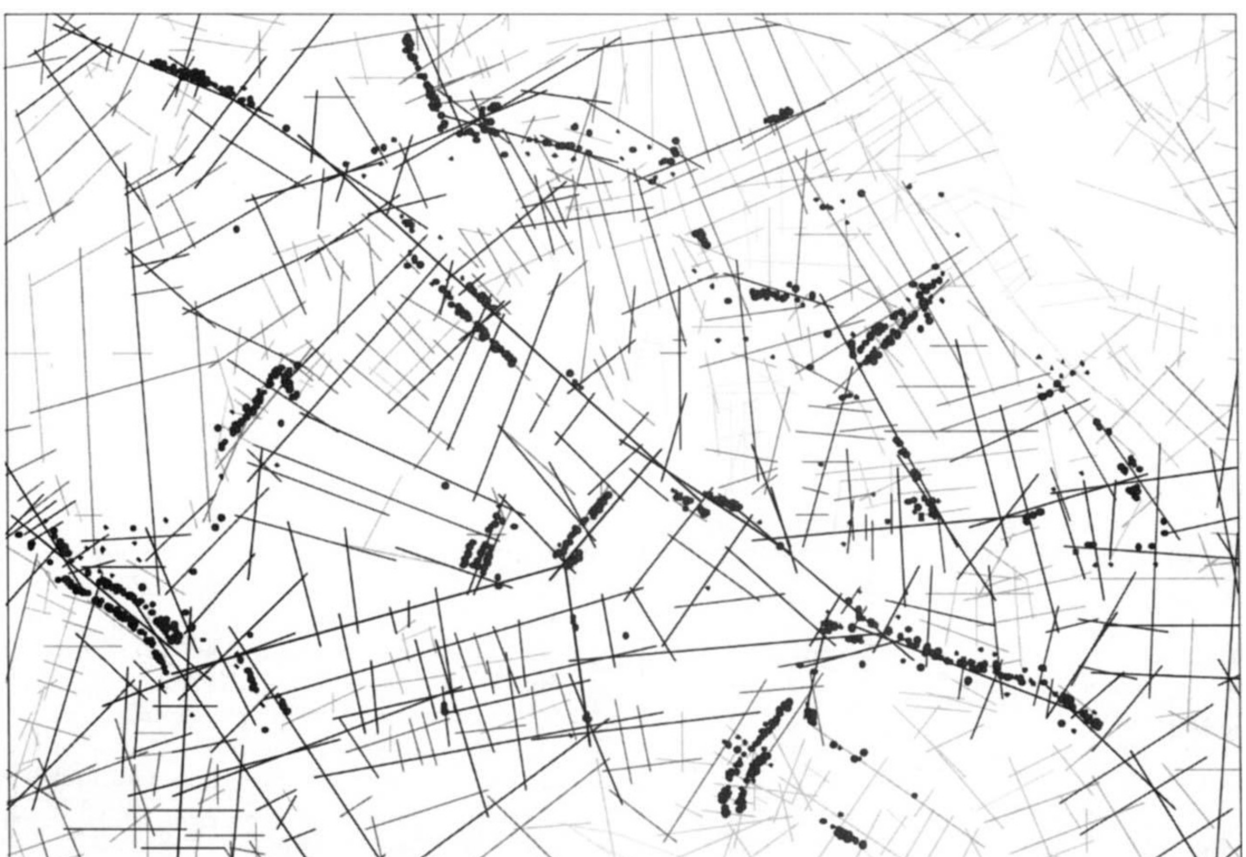

Fig. 7. Camden shops.

integration in the area. Once again, local grid conditions are shown to be the key variable associated with the degree of local centrality.

The transect method

In all the cases we have considered so far, retail is essentially linear in its spatial organization, usually on a single line, though occasionally on two or more intersecting lines. Some degree of linearity will always be retained, to a greater or lesser degree in different circumstances, but in the next section we will see how retail moves from a linear towards a convex form of organization in the centre itself. We will examine this through a new heuristic, this time aimed at main urban centres. In this series of studies we will use the work of Dr Kayvan Karimi, carried out (though not using the transect method) as part of his doctoral research.

Consider first a town with a fairly well-defined historic centre – York. Figure 9 is a first-order axial analysis of the whole built-up area of York showing global integration. The main integrators are a sequence of lines passing east–west through the main retail centre, with the line actually in the main retail centre (Micklegate) as the principal integrator. As with London, we have clues to centrality, but not an account of the centre itself.

Suppose we then make a simple proposition. If local grid conditions are different in the centre, then a route from the edge of the city through the centre and out the other side recording the changing local grid conditions ought to provide some indication of these differences. Figure 10 is a 'transect' of York taking the main through route (though not passing down the main shopping street) from the north-west to south-east through the central area and attaching the three-deep local grid to the route, one more than in the London case to allow for the greater deformity of the grid. A two-step transect tells a similar story, but the three-step transect is clearer. The transect shows the changing 'local grid conditions' associated

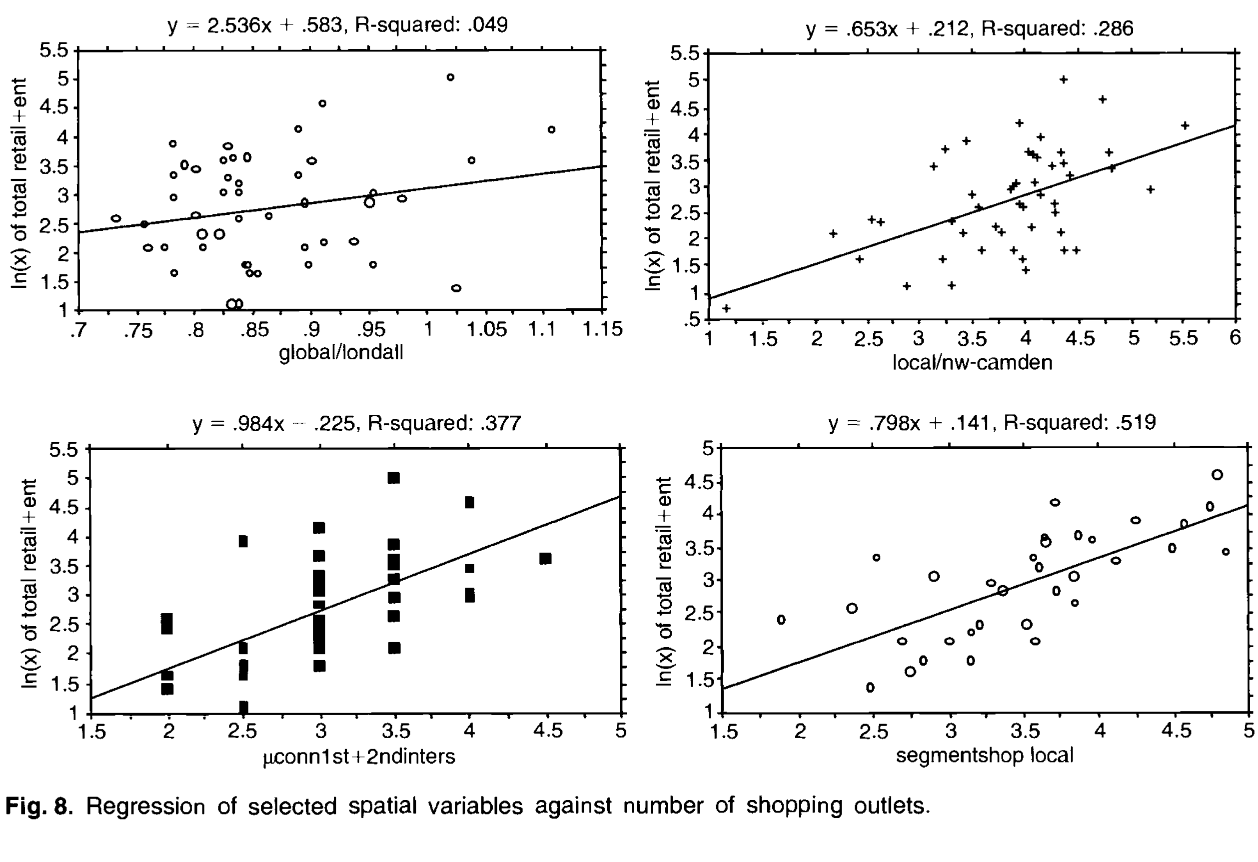

Fig. 8. Regression of selected spatial variables against number of shopping outlets.

Fig. 9. Integration map of York.

with each stretch of the route. To facilitate comparison, Fig. 11 then divides the three-transect into sections, defined by relative gaps in the local grid. This also allows independent syntactic analysis of each section, the results of which are set out in Table 1.

Visual inspection of Fig. 11 shows that the central area is disctinctive in several ways.

- The metric area covered by the three-step grid in the central area is both more compact and convex than other sections of the route. The route lines in the centre are relatively short compared with other sections of the route, and the lines up to three steps deep from the route tend also to be shorter.
- However, in spite of the relative shortness of the lines, the number of islands (or urban blocks) defined by the lines in the centre is much larger (31) than anywhere else. If we look along other parts of the route then we find that many – or in some cases most – of the lines do not define islands at all (that is, they do not form part of the local rings of circulation that must, by definition, surround urban blocks) and others define one or two blocks only. In the centre, the lines tend to help define several blocks in spite of being shorter.
- The previous two points imply that the mean size of island in the central area must be much smaller than elsewhere, and this is clearly the case.
- The blocks in the centre are densely packed in an overall convex shape with a high area–perimeter ratio, i.e. approximate a circular or square form, rather than a jagged, fragmented or elongated form. This is a functionally interesting property since, other things being equal, the more a shape approximates a circle (as a square does) the shorter will be the mean trip length within the shape.

Figure 12 then shows the 'live centre' – the principal streets with continuous shopping – of York, part of the centre section identified by the transect (which passed alongside the main shopping area). The overall convex and compact shape of the centre is preserved, though with rather more elongation in the north–south direction than the east–west direction. We see that dense retail does not develop in the looser grid to the east of

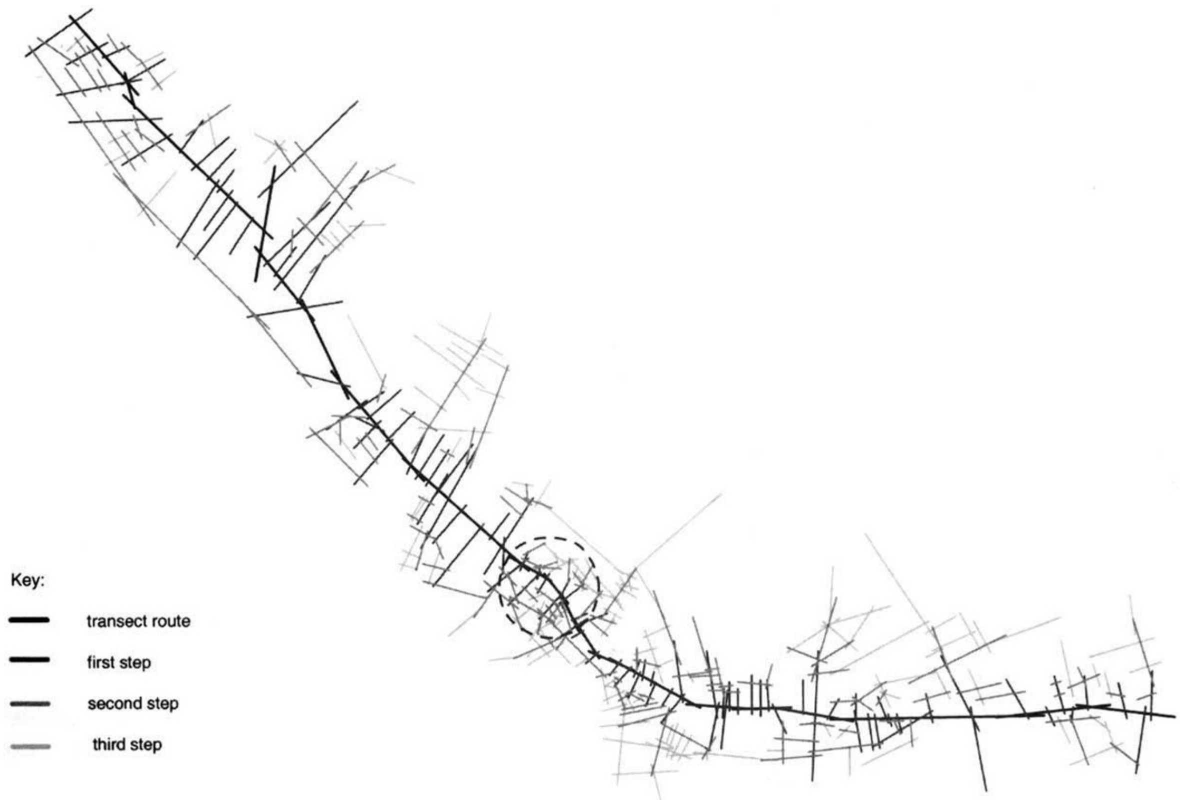

Fig. 10. Transect analysis of York (grid pattern created by up to three steps away from a through route in York).

the transect route to the same degree as to the west, where the grid is smaller scale. Within the live centre area, nearly all the internal small-scale streets also have continuous retail, and a market square is also to be found here. To the east it tends instead to form short 'spikes' leading in and out of the main retail area to the west.

This distinctive 'compact and convex' shape of the live centre, with a more intensive internal local grid, turns out to be very characteristic of town centres in the UK. For want of a better term, we have called this shape a 'spiky potato' to capture the irregular approximation of compact convexity, and also to capture the relatively short links that usually link the convex shape outwards into the surrounding area. Spiky potato forms are also found in similar analyses of four other towns by Karimi (1997). Figure 13 shows three-transects for Winchester, Hereford, Canterbury and Norwich, and Fig. 14 extracts the 'live centre' from each. In each case, a compact and convex shape appears, with more linearity in smaller cases, and more convexity in larger.

Table 1 then sets out the main syntactic values for the transect sections of all five towns, from edge to live centre then out to the opposite edge. We see that, in each case, three critical syntactic values: local integration, global integration, and the correlation between the two (the latter indicates the degree of symbiosis or synergy between the local and global patterning of space, a vital property of space in urban areas – see Hillier, 1996a and 1996b), all increase as you move towards the centre, peak in the live centre, and then reduce as you progress to the opposite edge. The numerical pattern is remarkably consistent, and confirms the results of the graphical appraisal. As you move towards the live centre, the grid becomes more compact, convex and subdivided, and at the same time more integrated and with a better defined relation between the global and local structure.

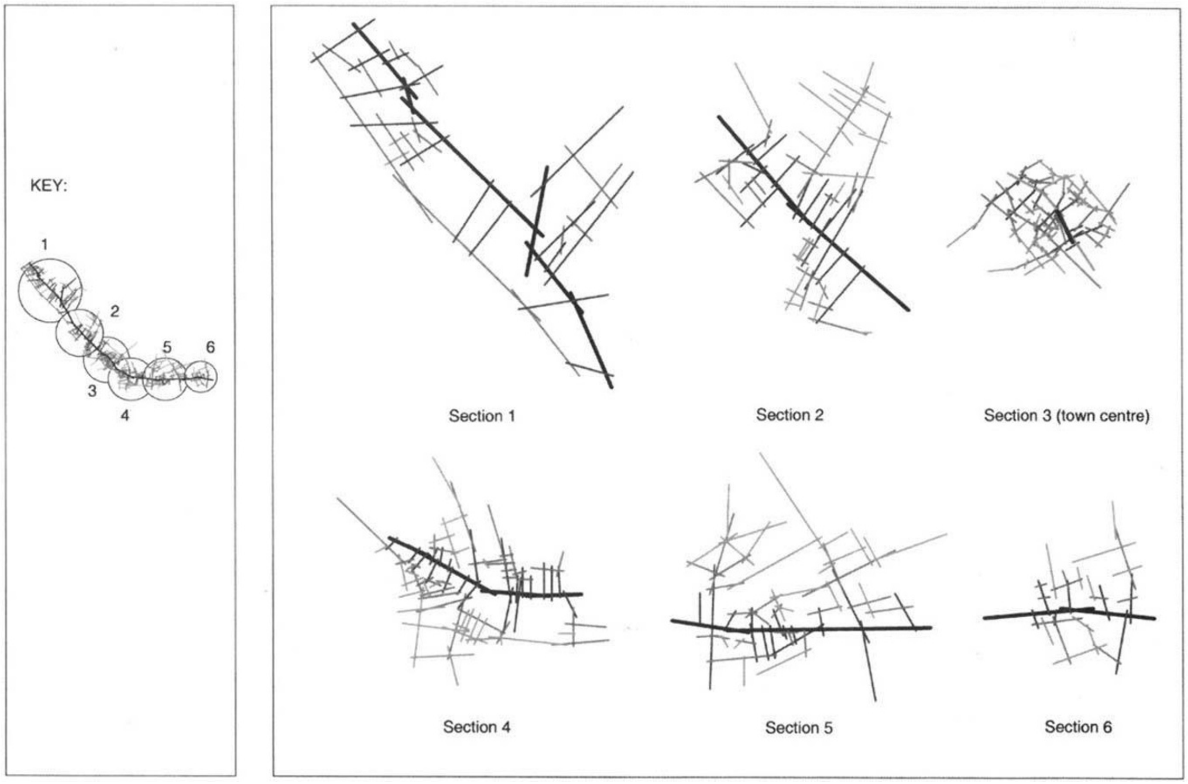

Fig. 11. Sections of transect analysis in York.

The results, though preliminary, suggest that there may be clear syntactic correlates for centrality, and that these can express in numerical form some of the characteristics of a compact and convex shape with short links outwards on integrated lines linking into the surrounding area coupled to a dense internal grid with small islands. The overall spiky potato shape formed by the live centre is also remarkably consistent, though always reflecting to some degree the linear nature of the original generators of the live centre. Karimi in fact notes that in Iranian cities the live centre tends to remain more linear with slower development of a convex form (Karimi, 1997).

Interdependence, interaccessibility and the shape of centrality

Why then should these be the properties associated with centrality? They are, it is suggested, all natural products of the movement economy process. Town centres, it is suggested, can be defined as complexes of **interdependent** facilities, so that if you come to use one, it is easy to use others. The criterion for whether or not a development would be 'part of the town centre' reflects this interdependence: if people come to use this, will they also use other facilities in the centre? Whether or not interdependenc is effective depends on **interaccessibility**: it must be possible to get from any facility to any other by a quick and easy route which stays within the town centre and which itself is lined with town centre facilities to maximize natural access to all facilities.

In a town centre, in short, it must be possible to search, explore and find, and the basic rule is that wherever you get to, you can still find an easy route to anything else you want to visit without going back over the same route. Interaccessibility should also be reflected in the pattern of access to the centre: whichever direction you approach the

Table 1. Mean syntactic values for the transect sections of York, Norwich, Hereford, Canterbury and Winchester

cities	Number of lines	Global integration	Local integration	Correlation between global and local integration
York				
York far west	40	1.0911	1.7919	0.6329
York centre-west	51	1.2241	1.7795	0.5374
York centre	74	1.3696	2.2954	0.7026
York live centre	**62**	**1.5069**	**2.3201**	0.7212
York centre-east	85	1.2949	2.055	0.5371
York east	59	1.2733	1.9338	0.5258
York far east	29	0.9692	1.459	0.5078
Norwich				
Norwich north	158	1.4936	1.9357	0.6141
Norwich centre-north	86	1.3419	2.3198	0.5839
Norwich centre	114	1.4472	2.4086	0.7398
Norwich live centre	**64**	**1.5866**	**2.4631**	0.7861
Norwich south	141	1.4164	2.2176	0.5055
Hereford				
Hereford west	99	1.2147	1.9024	0.5024
Hereford centre	91	1.4479	2.1934	0.7029
Hereford live centre	**45**	**1.5071**	**2.3158**	0.7184
Hereford centre-east	74	1.3512	2.1247	0.6391
Hereford east	43	1.0579	1.8242	0.6704
Canterbury				
Canterbury west	37	0.9777	1.9654	0.3449
Canterbury centre-west	123	1.4809	2.036	0.6399
Canterbury centre	118	1.5392	2.2109	0.7348
Canterbury live centre	**59**	**1.6411**	**2.3593**	0.7642
Canterbury east	35	1.1391	1.9099	0.3744
Winchester				
Winchester west	109	1.1225	1.9318	0.4348
Winchester centre	113	1.7081	2.3469	0.7639
Winchester live centre	**59**	**1.8856**	**2.4684**	0.8084
Winchester east	88	0.8208	1.9033	0.4729

centre from, the whole centre should quickly make its interaccessibility available and obvious. The effect of this will be that although bits of the centre grow out along these routes to some extent, it will happen in such a way as to conserve the integrity of the whole. The overall shape of a town centre is thus an overall compact convex shape with spikes – the 'spiky potato' – with a series of quantifiable spatial characteristics reflecting interaccessibility which peak in the live centre, and fall off towards the edges of the settlement.

From a spatial point of view, then, centrality seems to be a product both of the overall configuration of the grid, which decides where the centre should be, and the kind of local process of grid adaptation and intensification predicted by the theory of the movement economy, and described by Siksna (Siksna, 1997) in his studies of American and Australian centres. In our small sample of towns, we find that in each case, the 'live centre' develops as a 'compact and convex' shape, with links reaching into the surrounding area in all key directions. It is this 'spiky potato' shape, coupled with its high internal integration and local-global symbiosis, that creates the interaccessibility required by the interdependent facilities of the live centre, and which is created as the

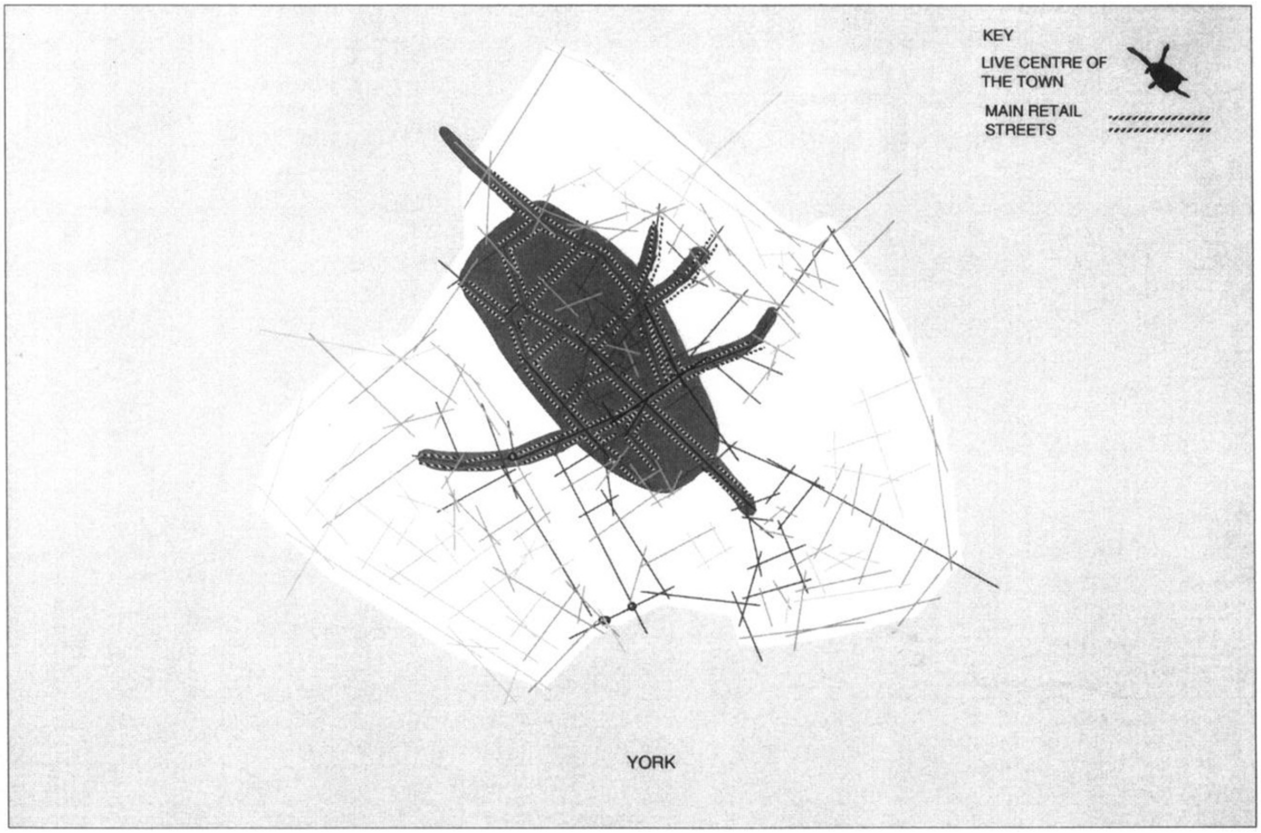

Fig. 12. Live centre of York (integration analysis and the main retail streets are shown for the central grid).

settlement evolved by the processes of natural movement and the movement economy. Successful live centres require both a global position in the settlement, and compact and interaccessible local layout conditions. This is the basic shape of centrality.

Reflections on centrality

We have now looked at several kinds and scale of centrality, in different urban situations. Can they be linked together into a single conjectural model? The following might be suggested:

- initially, the live centre is linear, on a section of a most integrated line, probably defined in relation to its most integrated intersection;
- as the settlement grows, a convex Siksna process of grid intensification and metric integration develops in the live centre;
- with linear growth away from the centre, local subcentres develop on radials selected by local metric two-deep conditions, but in themselves remain linear;
- with further growth, smaller-scale subcentres develop away from main radials where there is a locally strong two-deep structure but without metric two-deep conditions.

In general, the 'Siksna process' of convex live centre formation seems to be governed by scale. Only a major centre is strong enough to call it into play. Weaker centres tend to remain more linear. In all cases, however, local grid conditions are critical to the live centre, initially selecting between integrated locations by providing a locally accessible catchment area, and subsequently by providing the logic of growth of the live centre from a linear to a convex form.

Movement generators of centrality

How then does centrality fit into the overall logic of the urban grid? In a recent paper on the

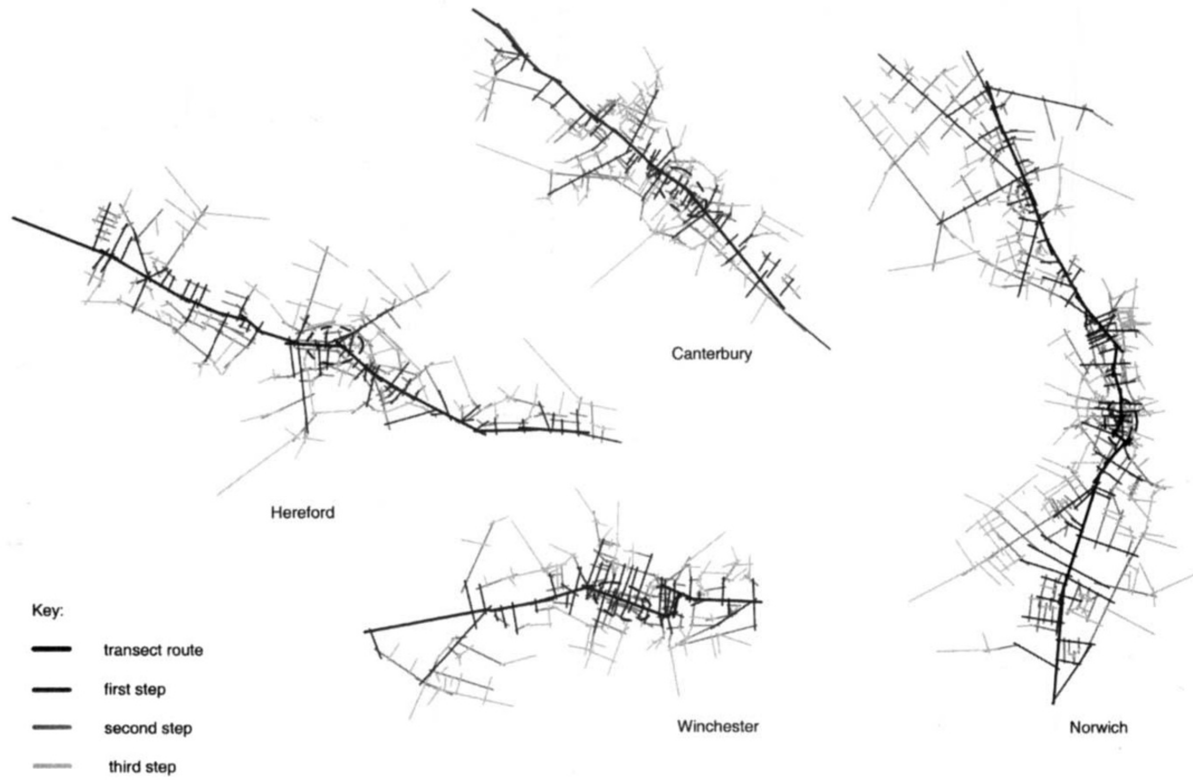

Fig. 13. Transect analysis of four English towns (grid pattern created by up to three steps away from a through route in four English towns).

geometry underlying the deformed grids of organic cities (Hillier, 1999) it was proposed that the fundamental influences shaping the evolution of large-scale urban grids were two kinds of movement. The first is linear movement from specific origins to specific destinations. The dominant manifestation of this are the quasi-linear radials that connect the central areas of cities with their edges, as so frequently picked out by syntactic analysis. These alignments are usually composed of long lines, or sequences of fairly long lines, connected to each other by obtuse angle intersections, thus minimizing distance from origin at the edge to destinations in or around the centre. These can be clearly seen in the map of London in Fig. 1. This pattern is pervasive in the sense that a peripatetic observer moving around the grid who finds an obtuse angle connection continues along the alignment would be very likely to find another obtuse angle connection continuing the alignment . Once this had occurred the probability of another would be even greater. The distribution of angles of incidence for lines was thus seen as playing a key role in making the urban surface intelligible. We can call this kind of movement moving-to, and note that it generates forms which are essentially one-dimensional.

In contrast to this, the second kind of movement is 'moving around' movement within a local area, and relates all origins and all destinations within that area. This type of movement is essentially convex in form, and optimally generates not quasi-linear sequences of lines connected by obtuse angles but quasi-grids, in which lines intersect appromimately at right angles, and continue to form other quasi-right angle intersections with other lines. This process has the effect of optimizing 'metric integration' in two dimensions, that is minimizing mean trip lengths from all points to all others within a two-dimensional zone, as opposed to metric integration in one-dimension for the quasi-linear radials. The two-dimensional zone where this process is maximized is the centre of the settlement, but it

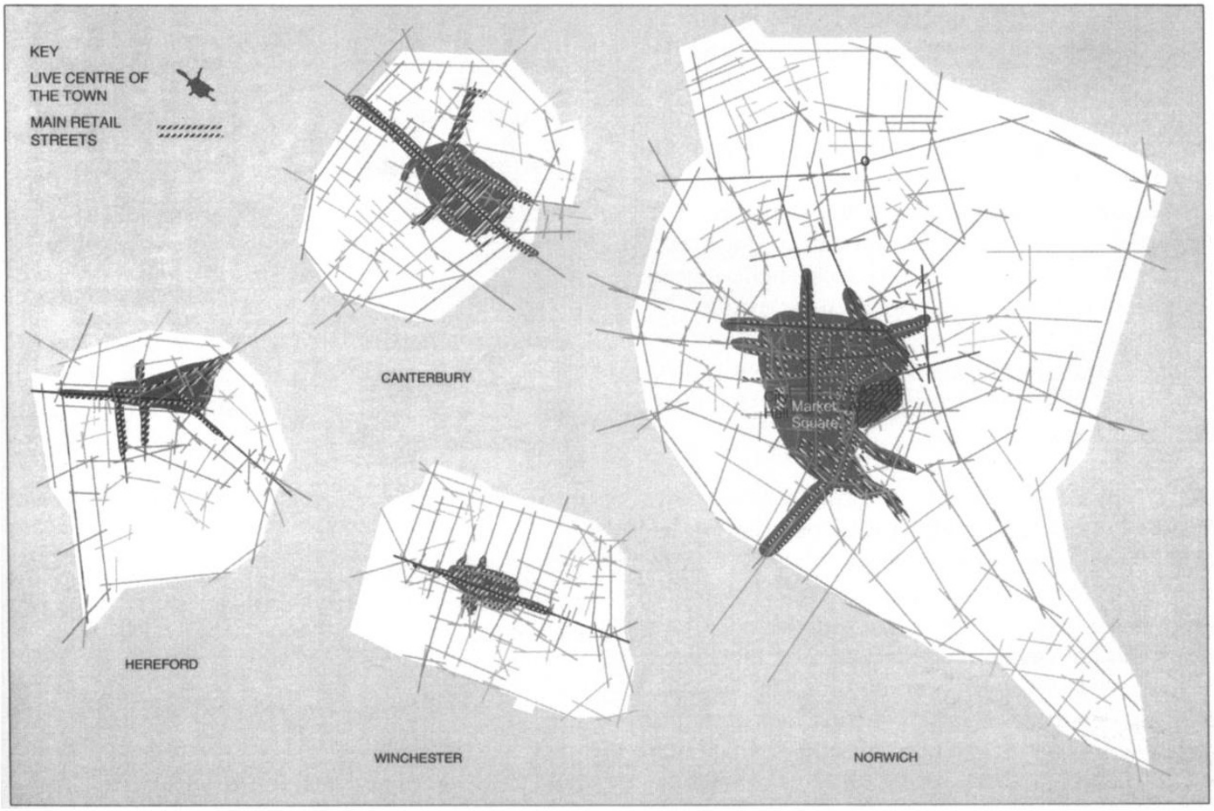

Fig. 14. Live centres of four english traditional towns (integration analysis and the main retail streets are shown on the central grid).

also occurs in other parts of the settlement and where it does it generates subcentrality proportionate to its local grid development. Thus, one-dimensional radial structure defines where the centre is to be, and eventually creates the spikes that link the compact and convex central shape into the one-dimensional system, while the compact and convex shape itself is the product of the movement economy process working two-dimensionally in the vicinity of the lines selected by the one-dimenesional structure.

The centrality process is thus driven by distance minimization in one dimension and in two. One-dimensional distance minimization generates the main radial structure of the grid, as usually picked out by the global integration core of the settlement. Two-dimensional distance minimization creates the local metrically and/or syntactically integrated quasi-grids that form the distribution of attraction inequalities in the grid. One-dimensional movement defines where the movement economy process will operate to generate local or global centrality. The two-dimensional process is then the means by which the movement economy process creates its attraction inequalities.

Given this theoretical model, we may now reflect on its intrinsic dynamics. As we will see, exploration of these dynamics suggests, in fact, that all the properties we find in centres – a compact and convex shape, a small scale internal grid, and so on – arise from optimizing a single variable: 'metric integration' (Hillier, 1996a, Chapter 3) – and with the unexpected bonus that we can begin to show that the idea of attraction not only interacts with configuration, but in fact has a configurational interpretation so that we can unify the two concepts.

Metric integration and attraction

The idea of metric integration arises from the suggestion that the success of syntactic integration as a measure is that it is ultimately an expression of 'universal distance' (Hillier, 1996a, Chapter 3). This is defined, in contrast to 'specific distance' which measures the distance from *a* to *b*, as the distance from one point to all others in a shape. In practice this is shown by representing a shape as an arbitrarily fine tessellation, then treating the tessellation elements as the nodes of a graph and the facewise joins between elements' edges. Configurational measures can then be applied in the normal way, giving results such as measures of shape expressing mean trip distance within the shape, and other measures analogous to area: perimeter ratios.

From the point of view of centrality, the interesting thing is how metric integration behaves under architectural and urban conditions. We can explore this by representing the axial map (or even the full two-dimensional shape of urban spaces), as a linear tessellation, so that each element of the tessellation is uniform in size. Integration analysis at radius-n thus measures the distance from each element to all others, that is its 'universal distance'. This can then be averaged for all tessellation elements and gives a measure of mean universal distance for the whole complex. The mean depth or integration from each cell to all others is thus isomorphic to the mean trip length from that cell to all others, and the mean integration of the complex is isomorphic to mean trip length in the complex as a whole. In Chapter 3 of *Space is the Machine* (Hillier, 1996a), it is shown that universal distance - and therefore mean trip lengths - in shapes will always by minimized in compact and convex shapes, and maximized in linear, jagged and otherwise non-convex shapes, following the logic of area: perimeter ratios.

On this basis we can construct experiments in which we hold steady the total travellable distance within a spatial system by keeping the number of modular elements constant within a standard envelope shape, and rearranging them so that all differences in mean trip length will be wholly due to the configurations in which we place these elements within the standard envelope shape. Figure 15, for example, shows four grids, each made up of 145 cells within a 17×17 envelope. Grid A is a straightforward orthogonal grid with uniform block size, which we will call the uniform grid. Grid B offsets the blocks east–west, thus increasing the number of axial lines,

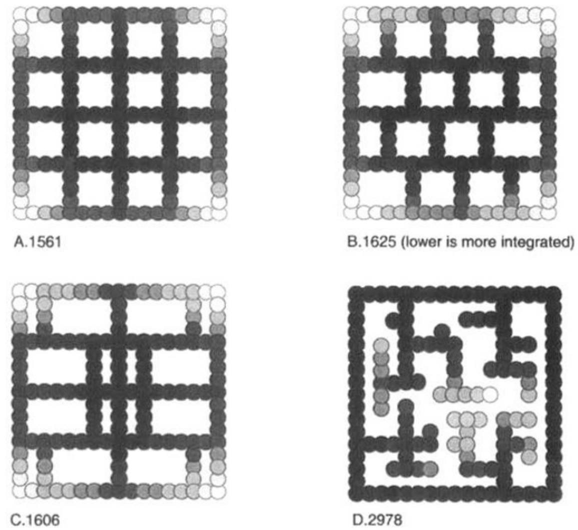

Fig. 15. An orthogonal grid (A) with fewest axial lines is metrically more integrated than axially more complex structures.

but keeping block size fairly uniform. Grid C offsets blocks and varies block size more substantially. Grid D is a tree structure with, in effect, a single, highly non-convex internal block. The integration value is derived by computing the total depth (and therefore the total metric distance) from each cell to all others, then carrying out the usual normalization to give an 'integration' value in which a lower value means greater integration, or lower mean trip length from all cells to all others. Grids B, C and D all have less integration or greater mean trip lengths than Grid A.

Figure 16 then combines the four grids into a single system and re-analyses. The distribution of shading shows that the darkest structure reaches further into the orthogonal grid and the top left than into any others, showing the 'attractor' effect of this grid. Unfortunately, with the current state of this software, mean integration values for subsets of cells cannot be calculated. We therefore compare the four subgrids on a cell-by-cell basis and find that in general comaparable located cells are more integrated in the top left grid than in the others. Pending a full test of this result with new software, we index each grid by the integration value of its geometrically central cell. We find that the top left, orthogonal grid has the lowest value and is therefore the most integrated.

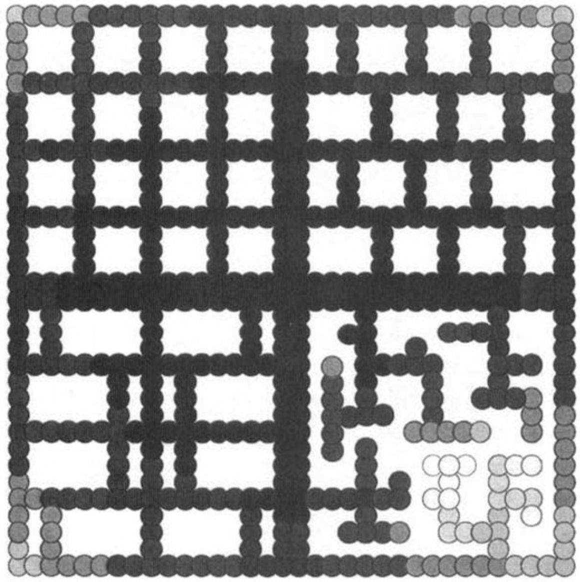

Fig. 16. If all are jointed into a single system, integration is attracted into the regular grid, as indexed by the values of the central cells in each subgrid: top left: 0.07267; right: 0.076405; bottom left: 0.076154; right: 0.101987.

In Fig. 17 we then hold the number of lines invariant and vary block size only. In Grid A, we move the two outer north–south lines one cell east and west, creating larger central blocks. The result is less integration ($i = 0.1585$) than in the uniform grid (0.1561). However, in Grid B, we move the same two north–south lines one cell inwards from their position in the uniform grid. We now find that the grid is rather more integrated than the uniform grid (0.1544), and the total distance to be travelled to go from each cell to all others is therefore decreased. In Grid C we then move the two inner east–west lines one cell closer in, making smaller and squarer central blocks, and larger outer blocks. The effect is even greater integration (0.1528). Finally, we take this process as far as possible within this 145 cell system and bring both north–south and east–west lines one cell further in, creating very small central blocks and much larger outer blocks. The result is an even more integrated system (0.1509), and therefore a system in whcih the total metric distance from each cell to all others is less than in any of the other cases so far considered. These results exactly follow the predictions in *Space in the Machine* (the partitioning theory, Hillier, 1996a, Chapter 8). Larger central blocks decrease integration, and small central blocks increase it, as predicted by the 'centrality' principle.

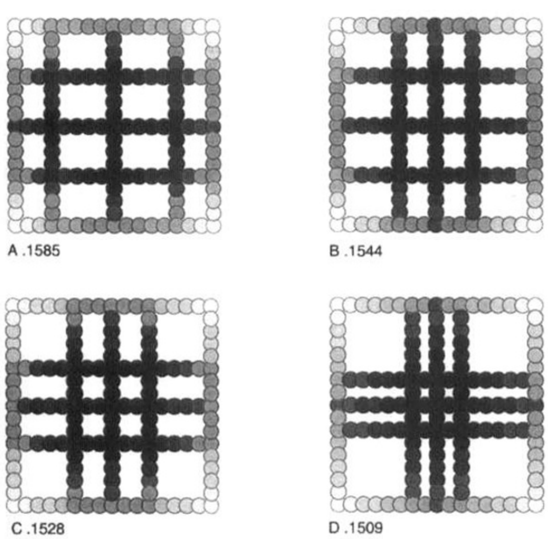

Fig. 17. If we vary block sizes in axially minimal (least lines) grids, we find that smaller blocks in the centre make for better integration (least mean trip lengths for the system as a whole) than any other configuration. This follows the principles for the construction of integration set out in Hillier (1996a, Chapter 9).

In Fig. 18, we assemble all four of these grids into a single system and re-analyse. Central cell values (which are already in themselves indicators of a key property) for each subgrid in the whole system follow the integration values of the separate grids. The most integrated central cell is in the bottom right subgrid, with its small central and larger outer blocks, the second is the top right, with its two verticals moved one cell in, then the uniform grid at bottom left, and finally the top left, with the two vertical moved outwards. Again this confirms that (other things being equal) a more integrated subcomplex will act as an overall attractor in any system of which it is part.

Attraction and configuration

From the point of view of centrality, these theoretical results ar remarkably interesting. Not only do they show that variations in grid form lead to differences in mean trip lengths, exactly following the logic outlined in the 'partitioning theory' set out in *Space is the Machine* (Hillier, 1996a, Chapter 8) but also that the directions of optimization all track the properties found in settlement centres: compact and convex shapes,

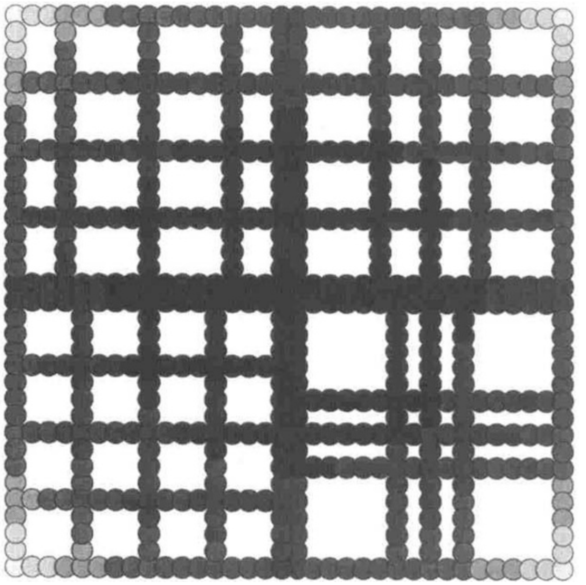

Fig. 18. If the four grids are combined into a single system, then integration is attracted into the most integrated system, that is, the one with smaller central blocks, as indexed by the central cells values: top left 0.070970; top right: 0.070397; bottom left: 0.070684; bottom right: 0.070111.

small islands, preferably in the centres, and continuous lines rather than right angle changes. Prima facie, metric integration seems to be the master property of centrality at all levels, though within a discipline initially imposed by the fundamentally linear logic of urban space.

More remarkably, the grid intensification that come from this process of optimization (the Siksna process) itself sets up global attraction towards itself with respect to the grid as a whole. This means that if the theory of natural movement holds up under these conditions, then a more integrated local grid will have higher internal rates of movement due to the attractor effect of the local grid, before we even consider the load of attractors imposed on this by the movement economy process. This mirrors results already found empirically in Penn (1998) and Read (1999), though not previously explained.

This theoretical relation between configuration and attraction is an unexpected bonus in the project of exploring the degree to which the pattern of attraction inequalities in the urban grid – the pattern of centres and subcentres – can be explained though the movement economy process, and can therefore justify the axiom: configuration generates attraction. The evidence we have adduced for this proposition is of course indirect: we have sought to identify a process by its products. However, the unexpected theoretical linking of configuration and attraction through metric integration does lend extra force to the evidence that has been marshalled in taking these first steps towards a spatial theory of centrality. Both empirical and theoretical results thus suggest that far from being distinct properties, attraction and configuration are bound to each other not only through the processes by which attraction inequalities arise in the urban configuration through the operation of the movement economy, but also, in a more purely spatial sense, within the idea of configuration itself. This raises the possibility that it might in due course be possible to characterize the pattern of 'centres and subcentres' in the urban surface in general as 'attraction inequalities' produced by the movement economy process working through the spatial process of metric integration.

References

Batty, M., Thurstain-Goodwin, M., Cadell, C. *et al.* (1998) *Town Centres: Defining Boundaries for Statistical Monitoring: Feasibility Study*. London, Department of the Environment, Transport and the Regions.

Hillier, B. (1996a) *Space is the Machine* Cambridge, Cambridge University Press.

Hillier, B. (1996b) Cities as movement economies, *Urban Design International*, **1**, 49–60.

Hillier, B., Burdett, R., Peponis, J. and Penn, A. (1987) 'Creating life: or, does architecture determine anything?' *Architecture & Behaviour*, **3**, 233–50.

Hillier, B., Penn, A., Hanson, J., Grajewski, T. and Xu, J. (1993) Natural movement: or configuration and attraction in urban pedestrain movement, *Environment & Planning B: Planning & Design*, **20**, 29–66.

Hillier, B. (1999) The hidden geometry of defomed grids: or, why space syntax works, when it looks as though it shouldn't, *Environment and Planning B: Planning & Design*, **26**, 169–91.

Karimi, K. (1997) Continuity and change in old cities: an analytical investigation of the spatial structure in Iranian and English historic cities before and after modernisation, PhD thesis. University of London.

Penn, A. (1998) (with Hillier, B., Banister, D. and Xu, J) Configuration modelling urban movement networks. *environment and Planning B: Planning & Design*, **25**, 59–84.

Read, S. (1999) Space syntax and the Duth city,

Environment and Planning B: Planning & Design, **26**, 251–64.
Siksna, A. (1997) The effects of block size and form in North American and Australian City Centres, *Urban Morphology*, **1**, 19–33.
Salah-Salah, F. (1987) *Cities in the Sahara: spatial structure and generative processes*, PhD thesius, University of London.