

## CENTRALITY AS A PROCESS

*accounting for attraction inequalities in deformed grids*

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**0 Abstract**

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 revitalise 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 revitalisation, sustaining or long term development of centres.

*Keywords: space syntax, centrality, attraction, configuration*

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**1 Introduction: 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 Professor Batty and his colleagues (Batty et al, 1997). 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 by 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 ben-

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efit 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 level it occurs in locations favoured by and influenced by the 'movement economy' process (as outlined in Hillier 1996a (Chapter 4) & b). 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 organisation in settlements first generates movement patterns, which then influence land use choices, and these in turn generate multiplier effects on movement with further feed-back 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 characterise 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 manifestation 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 scale of 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.

## 2 The phenomena of centrality

At first sight, understanding centrality in towns and cities does not seem to be problematic. Both spatial and functional aspects appear 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.

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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 this 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 Mزاب 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 1996, Chapter 9: 'The fundamental city').

Centres can also diversify with growth, and the tendency to functional specialisation 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 'hierarchy 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.

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## 2.1 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 Professor Batty points out (Batty 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 spatial case of our need to understand the relation between structure and function in cities. An understanding of centrality would most likely to 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.

## 3 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

figure 1. London Log integration Map

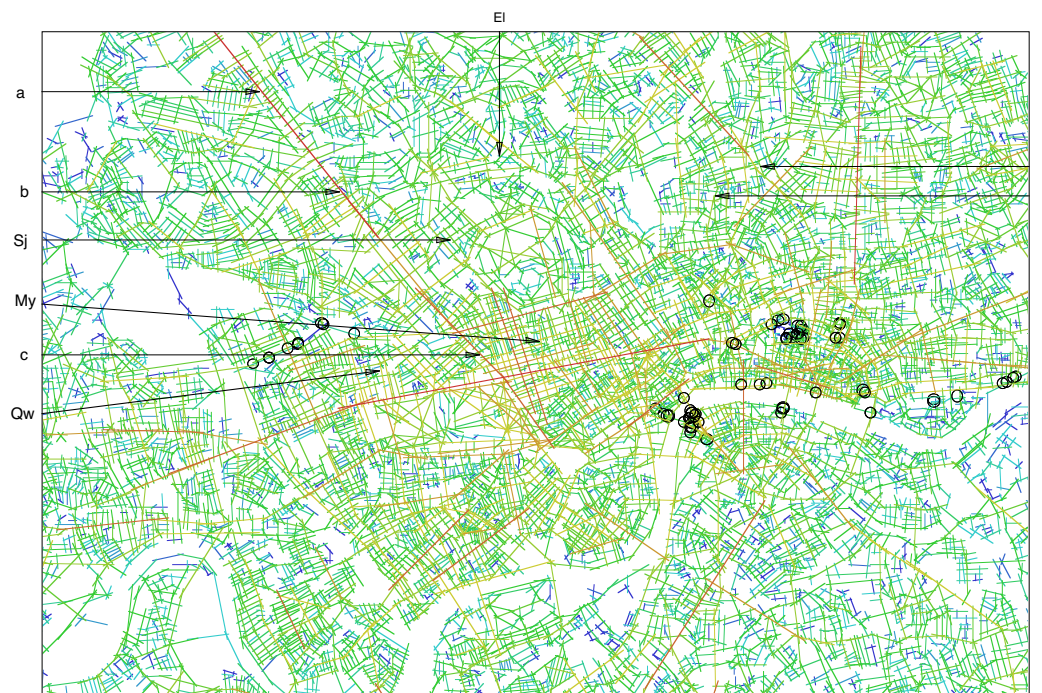


Figure 1: London (lograd-3)



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 uses 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 subcentres? Or are local grid conditions critical, as implied by Siksna's work? Do different spatial factors perhaps operate at different levels of centrality?

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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 Figure 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** in Figure 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 diagnostics - or perhaps heuristics would be a better word. Consider first the main north west radial in Figure 1, the Edgware 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 black background: Cricklewood High Street the most northerly, marked **a** in Figure 1, Kilburn High Street in the centre marked **b**, and finally the section between the Harrow Road to 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 characterised by a more intensive '2-step grid' than the noncentre 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 a 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 maximise local accessibility of dwellings to that line. Preliminary studies of other lines such as the Kingsland Road (top right arrow in Figure 1) suggest similar effects might be found elsewhere.

06.6

figure 2

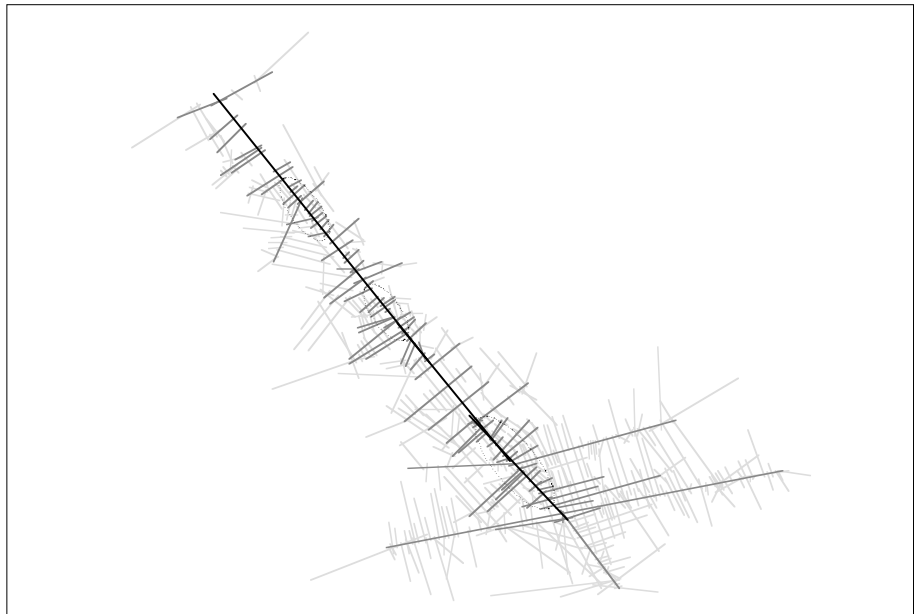


Figure 2: Edoeware Road

figure 3

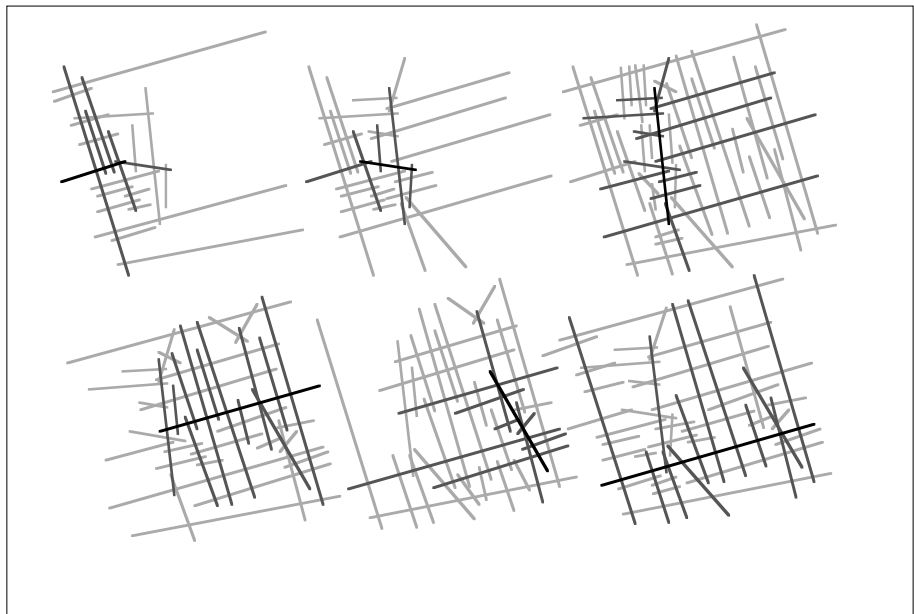


Figure 3: Marylebone Route Sequence

figure 4

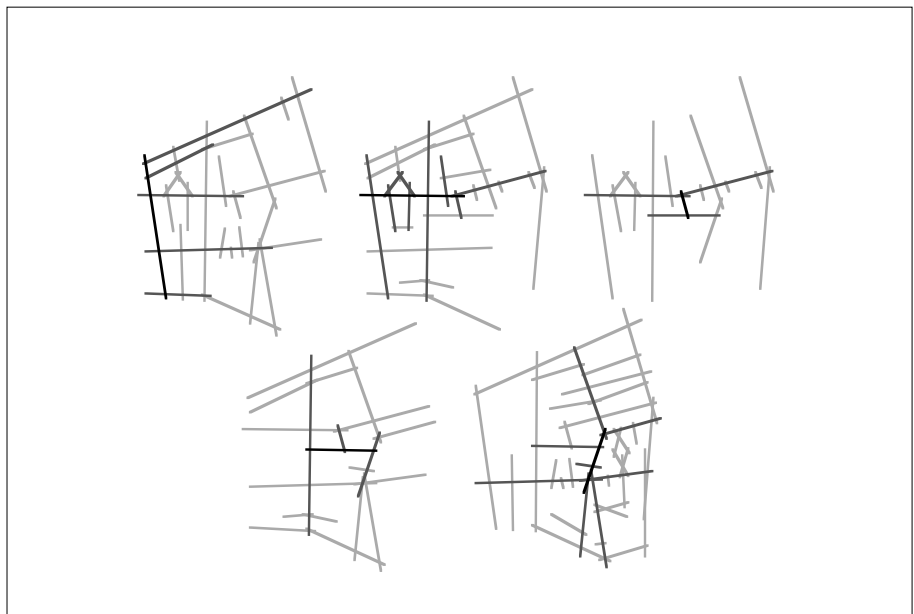


Figure 4: Barnsbury Route Sequence

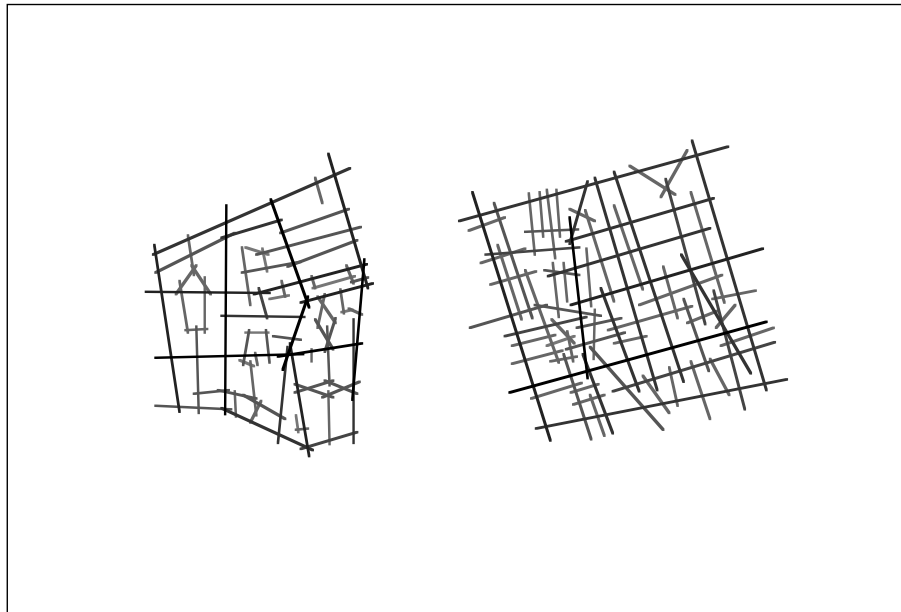


Figure 5: Marylebone and Barnsbury on their own

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figure 5

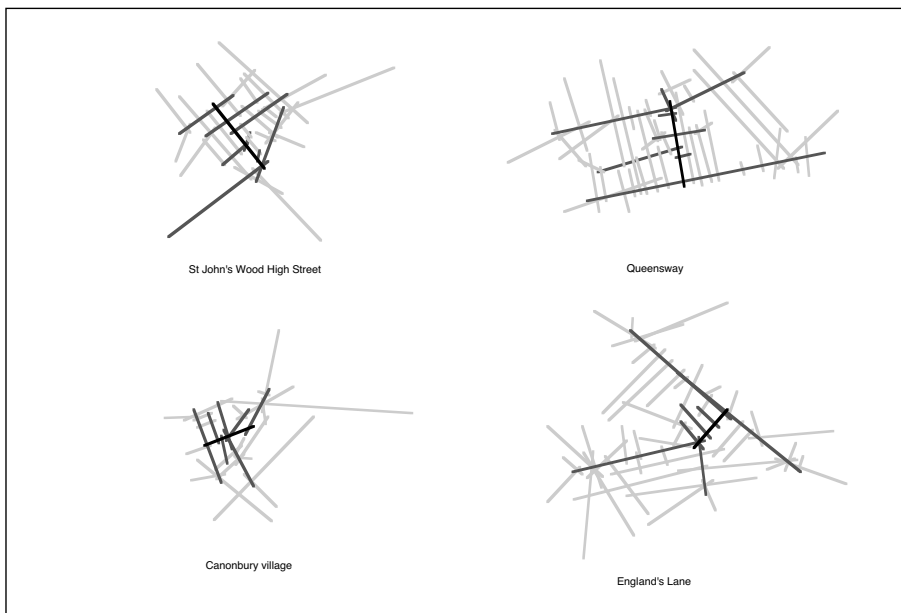


Figure 6: 2-step grids from selected live centre lines

figure 6a

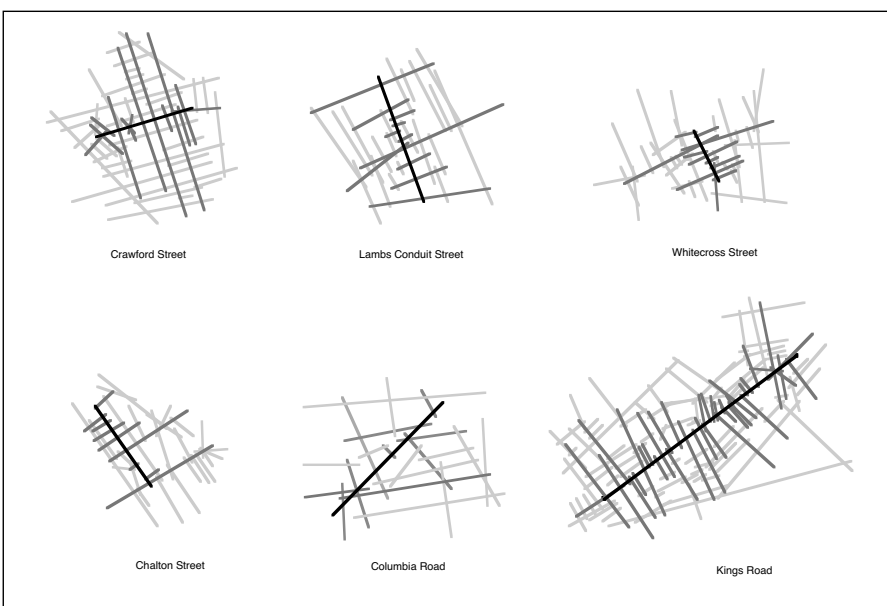


Figure 6b: 2-step grids from further selected live centre lines

figure 6b

## 06.8

However, if we look at the 'high streets' and 'village centres' not on main radials (marked with a capital and lower case letter on Figure 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 2-step grids from each line on the route. We see that the live centre line shown top right is distinctive in that it covers 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 - Figure 5), we can see why this is the case. In both cases, the live centre line is the principle 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 2-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, including three with street markets: Whitecross Street, Chalton Street and Columbia Road. In each case, the line is a relatively local line, though usually 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 2-step grid than other lines in the vicinity.

We see then that the 'local grid conditions', as shown by the '2-deep' grid from a line, thus seem to be a distinctive spatial property of live centre lines. Sometime the 2-deep grid describes a more compact and sometimes a looser structure, but the fact that in each case the same 2-step definition of local grid conditions does mark out the local centre as distinctive, albeit with varying metric properties, is suggestive. Now let us try a third heuristic. Figure 7 is an axial map of the northwest 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 in 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



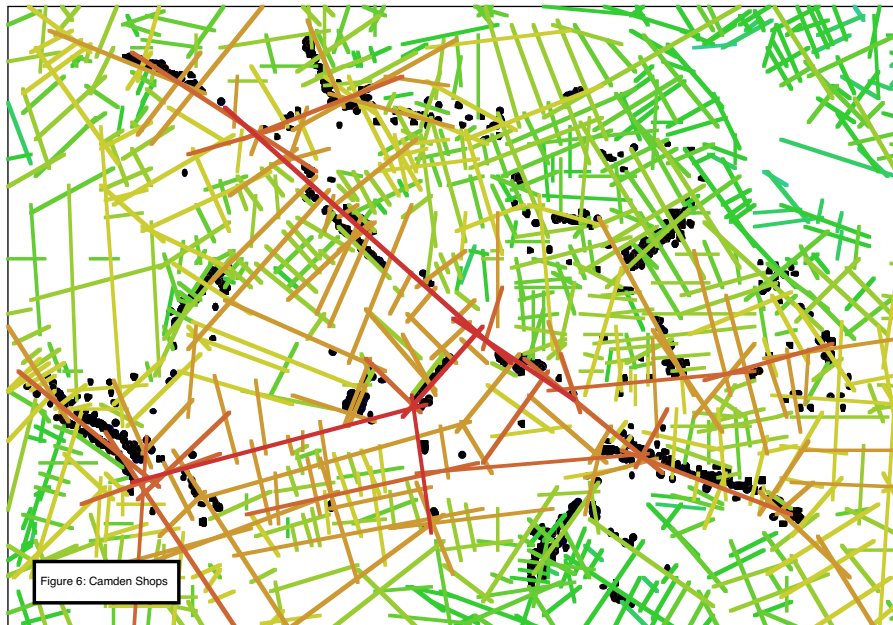
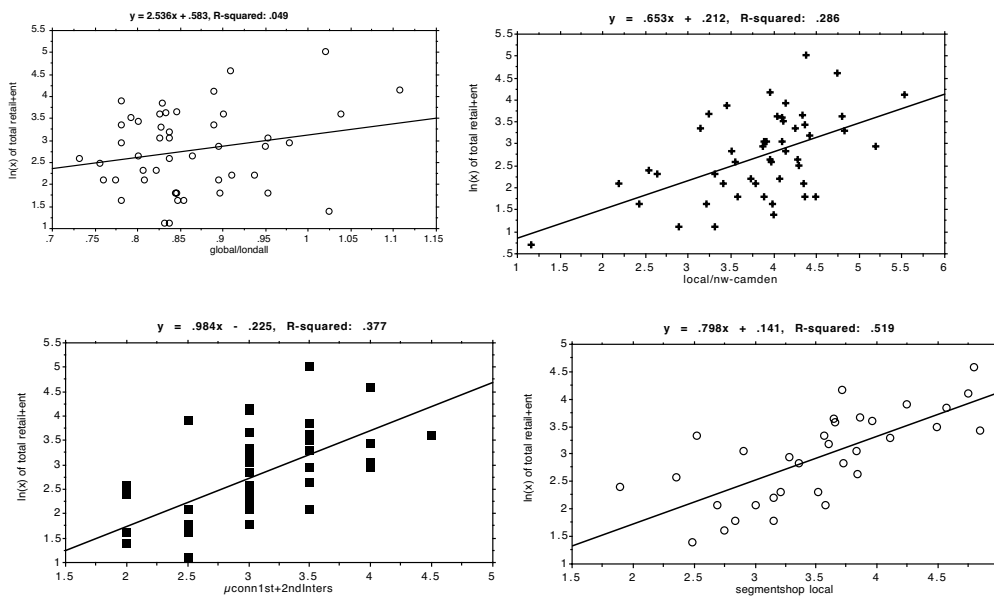


figure 7



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 or 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 .735 from 10 variables. The best r-squared for a single syntactic variable was .286 for local integration, the best for intersections was .377 for the sum of connectivities of intersection, but the best by far was .519 for local integration for segments (see below) - that is for the integration of the 2-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 integration in the area. Once again, local grid conditions are shown to be the key variable associated with the degree of local centrality.

## 06.10

**4 The transect method**

In all the cases we have considered so far, retail is essentially linear in its spatial organisation, usually on a single line, through 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 organisation 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 8 is 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 principle integrator. As with London, we have clues to centrality, but not an account of the centre itself.

Suppose we then ask a simple question. 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 9 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 3-deep local grid to the route, one more than in the London case to allow for the greater deformity of the grid. A 2-step transect tells a similar story, but the 3-step transect is clearer. The transect shows the changing 'local grid conditions' associated with each stretch of the route. To facilitate comparison Figure 10 then divides the 3-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 Figure 10 shows that the central area is distinctive in several ways:

- the metric area covered by the 3-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 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 point imply that the mean size of island in the central area must be much smaller than elsewhere, and this is clearly the case; and finally:



Figure 8: Integration Map of York

06.11

figure 8

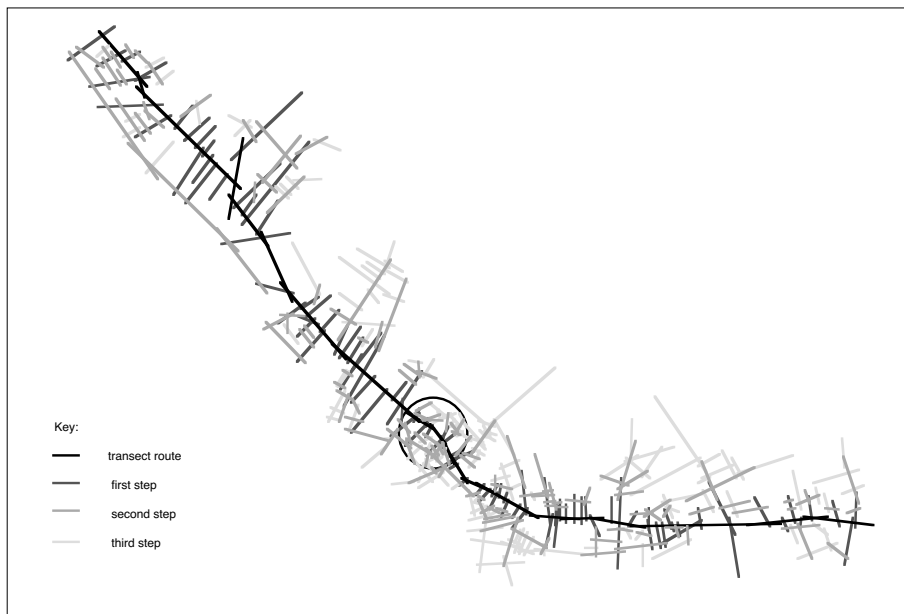


Figure 9: Transect Analysis of York (grid pattern created by up to three steps away from a through route in York)

figure 9

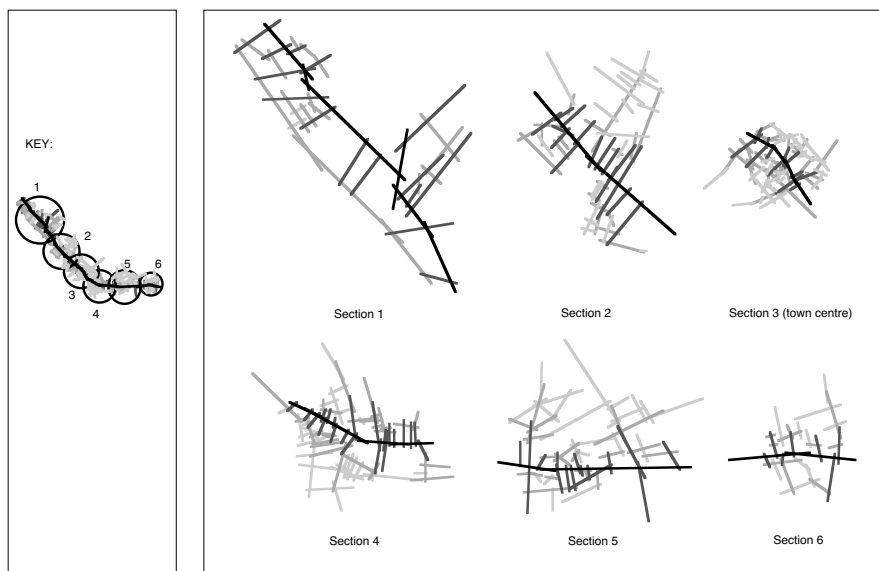


Figure 10: Sections of Transect Analysis in York

figure 10

## 06.12

- 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 11 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 the transect route to the same degree as to the west where the grid is smaller scale. Within the live centre area, the internal small scale streets in fact nearly all 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.

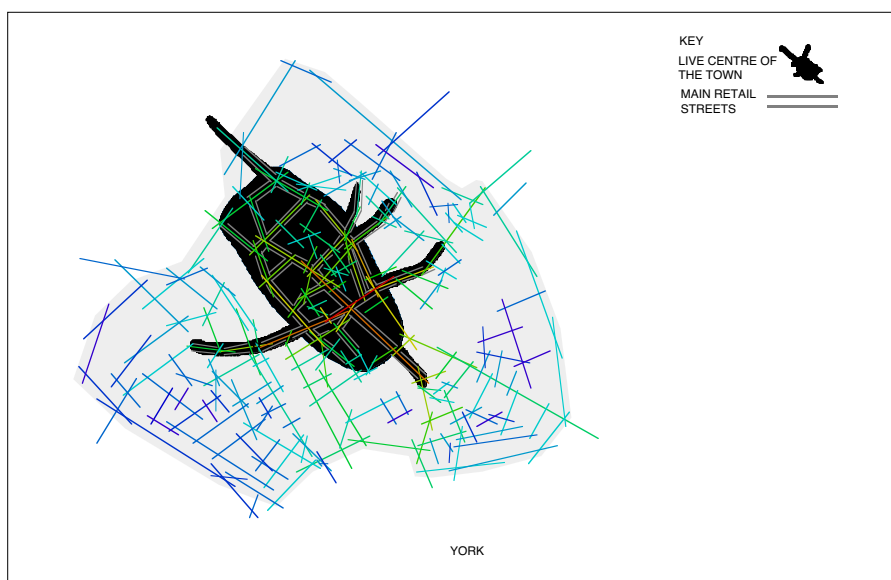


Figure 11: Live Centre of York (integration analysis and the main retail streets are shown for the central grid)

figure 11

table 1

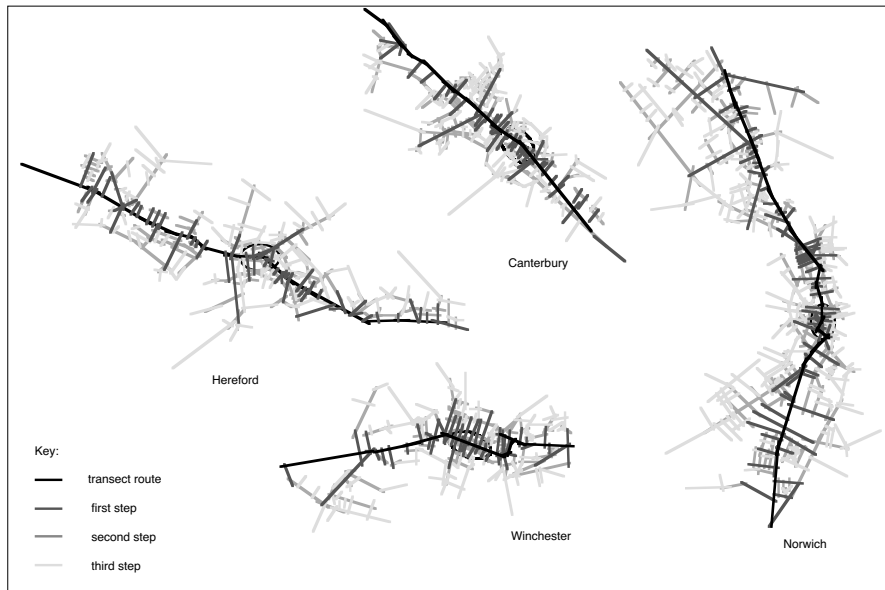


Figure 12: Transect Analysis of four English Towns (grid pattern created by up to three steps away from a through route in four English towns)

figure 12



Figure 13: Live Centres of Four English Traditional Towns (integration analysis and the main retail streets are shown on the central grid)

figure 13

internal local grid, turns out to be very characteristic of town centres in the UK. For want of a better term, we have call 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. Figure 12 shows 3-transects for Winchester, Hereford, Canterbury and Norwich, and Figure 13 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 1996, Chapter 4), 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 global and local structure.

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 lining 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).

### 5 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 interdependence 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 maximise 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 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 of the kind of local process of grid adaptation and intensification predicted by the theory of the movement economy, and described by Siksnas (Siksnas 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 that is required by the interdependent facilities of the live centre, and which is created as the settlement evolved by the processes of natu-

ral 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.

### 5.1 *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 2-deep conditions, but in themselves remain linear;
- with further growth, smaller scale subcentres develop away from main radials where there is a locally strong 2-deep structure but without metric 2-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.

### 5.2 *Movement generators of centrality*

How then does centrality fit into the overall logic of the urban grid? In a recent paper on the 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, and the dominant manifestation of this are the quasi linear radials that connects 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 minimising distance from origin at the edge to destination in or around the centre. These can be clearly seen in Figure 1 of London. This pattern is pervasive in the sense that a peripatetic observer moving around the grid who finds an obtuse angle connection and 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 seem 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 1-dimensional.

In constrast 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

## 06.16

linear sequences of lines connected by obtuse angles but quasi grids, in which lines intersect approximately at right angles, and continue to form other quasi-right angle intersections with other lines. This process has the effect of optimising 'metric integration' in two dimensions, that is minimising means trip lengths from all points to all others within a 2-dimensional zone, as opposed to metric integration in 1-dimension for the quasi linear radials. The 2-dimensional zone where this process is maximised is the centre of the settlement, but it also occurs in other parts of the settlement and where it does it generates subcentrality proportionate to its local grid development. Thus The 1-dimensional radial structure defines where the centre it to be, and eventually creates the spikes that link the compact and convex central shape into the 1-dimensional system, while the compact and convex shape itself is the product of the movement economy process working 2-dimensionally in the vicinity of the lines selected by the 1-dimensional structure.

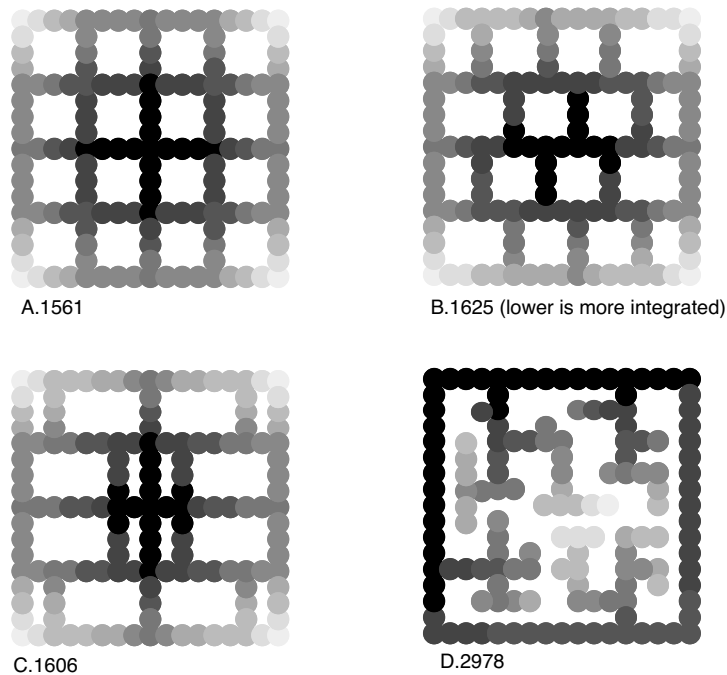
The centrality process is thus driven by distance minimisation in one dimension and in two. 1-dimensional distance minimisation generates the main radial structure of the grid, as usually picked out by the global integration core of the settlement. 2-dimensional distance minimisation creates the local metrically and syntactically integrated quasi-grids that form the distribution of attraction inequalities in the grid. 1-dimensional movement defines where the movement economy process will operate to generate local or global centrality. The 2-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 optimising 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.

## 6 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'. This is defined, in contrast to 'specific distance' which measure 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



06.17

Figure 14: An orthogonal grid (A) with fewest axial lines is metrically more integrated than axially more complex structures.

others, that is its 'universal distance'. This can then be averaged for all tessellation elements and give 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 be minimised in compact and convex shapes, and maximised in linear, jagged and otherwise nonconvex shapes, following the logic of area-perimeter ratios.

figure 14

On this basis we can construct experiments in which we hold steady the total travelable distance within a spatial system by keeping the number of modular elements constant within a standard envelope shape, and rearranging them so that all difference in mean trip length will be wholly due to the configurations in which we place these elements within the standard envelope shape. Figure 14 for example shows four grids, each made up of 145 cells within a 17 x 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, 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 nonconvex 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 normalisation 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.

06.18

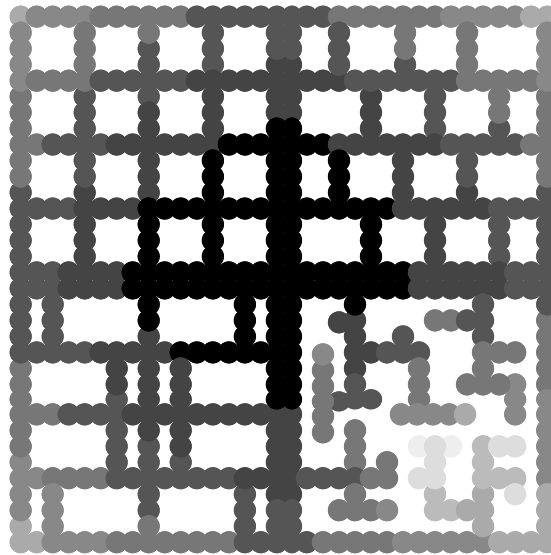


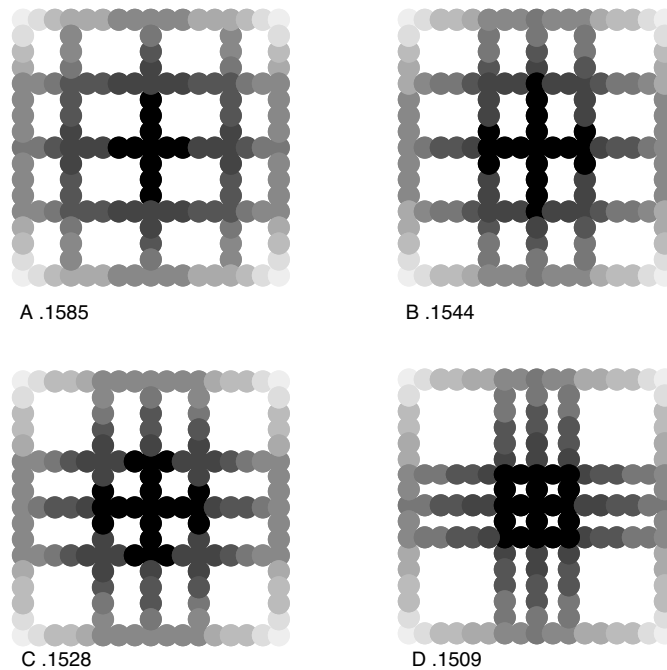
Figure 15: If all are joined into a single system, integration is attracted into the regular grid, as indexed by the values of the central cells in each subgrid: top left : .07267; right: .076405; bottom left: .076154; right: .101987.

figure 15

Figure 15 then combines the four grids into a single system and re-analyses. The distribution of colours shows that the red structure reaches farther into the orthogonal grid at the top left than into any others, showing the 'attractor' effect of this grid. Unfortunately, with the current 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 comparable 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.

In Figure 16 we then hold 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 ( $i = .1585$ ) than in the uniform grid (.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 now rather more integrated than the uniform grid (.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 (.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 (.1509), and therefore a system in which 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 Chapter 8 of 'Space in the Machine' (the partitioning theory). Larger central blocks decrease integration, and small central blocks increase it, as predicted by the 'centrality' principle.





06.19

Figure 16: 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 Chapter 9 of *Space is the Machine*.

In Figure 17, 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 left 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 right, 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.

figure 16

## 7 Attraction and configuration

From the point of view of centrality, these theoretical results are 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 Chapter 8 of *'Space is the Machine'* (Hillier 1996a, Chapter 8) but also that the directions of optimisation all track the properties found in settlement centres: compact and convex shapes, 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 optimisation (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.

06.20

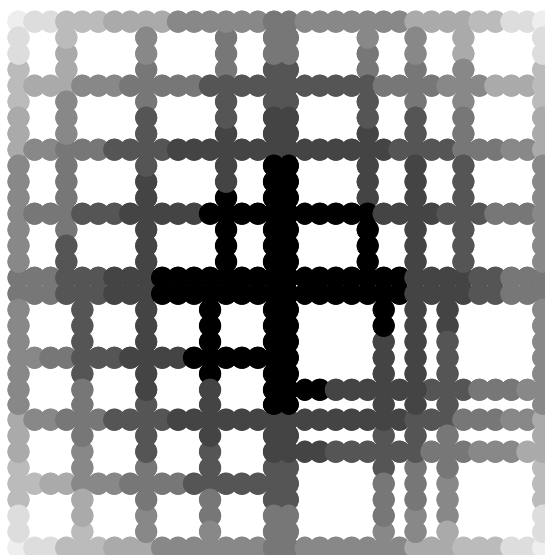


Figure 17: if the four grids are combined into a single system, then integration is attracted into the most integrated system, that is, the one with smaller central blocks, as indexed by the central cells values: top left: .070970; top right: .070397; bottom left: .070684; bottom right: .070111

figure 17

This theoretical relation between configuration and attraction is an unexpected bonus in the project of exploring the degree to which the pattern of attraction in equalities in the urban grid - the pattern of centres and subcentres - can be explained through 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 characterise 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.

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