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THE ART OF PLACE AND THE SCIENCE OF SPACE

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Abstract

Cities are large physical objects animated and driven by human behaviour.
How do the two connect? How do cities come into existence emerging from centuries of human activity as a well-ordered system? And how do they work to relate the physical patterning to the economic, social and cognitive life of human who inhabit it? The fact that cities exist and function as physical wholes at the global scale, but are experienced a bit a time at another, seems to trap us between an objectivist and rather abstracted view of the city as a whole and a subjectivist and phenomenological view of its parts. This paper aims to build up a theory of the city-creating process through the space syntax approach to overcome these two polarisations. The standing point is it treats cities as spatial networks and regards space as the common medium of the physical city and the experiential city, as well as of the socio-economic city and the cognitive city. So seen spatially, the physical city and the experiential city seem to merge into one.

How should we talk about cities as space then? I will first explain my approach to space - the space syntax approach and how it has come be used in research and design, both as a method and as a theory of space. Secondly, I will then show how we can use the method and the theory to bring to light certain key features of how human beings understand, experience and manipulate space. Armed with a theory of space itself, and a theory of the human understanding of space, a theory of the city-creating process in two stages will be outlined. One is a theory of how characteristically urban patterns of space are created by the aggregation of built forms and objects; the other is how collections of buildings become living cities by shaping human activity in them.
In conclusion, it is argued that cities are human products in a very strong sense. In their very form and function they reflect what we are and how we can be. Perhaps this is why cities are the greatest artefact.

Keywords**:** spatial network, city-creating process, axial analysis, segment angular analysis• space, art, science

Space in itself

Buildings and cities exist for us in two ways: as the physical forms that we build and see, and as the spaces that we use and move through. For most of the history of architecture, theory and criticism focused only on the first, the physical form. Then from the late nineteenth century on, as admirably documented by my colleague Adrian Forty (Forty 2000), architecture began to reflect on and theorise about space. Throughout the twentieth century, space was increasingly articulated as a dimension of architectural discourse, and by the end of the century most architectural and urban theories included a chapter on space, or indeed were in some sense theories of space (for a review see Benedict 1995)

But in spite of this growth of interest, there has been little consensus as to what space is, and why and how it matters. Everyday intuition tells us that the space created by buildings and cities exists for us as patterns of differentiated and related spaces, which somehow reflect or embody patterns of life. But this intuition has proved hard to address analytically, since it presents both philosophical and methodological difficulties. Philosophically, if we are to talk about space at the level at which we experience it, we must first believe it is a real phenomenon, with some independence from others. But this is hard to argue, for two reasons. First, space seems to be the emptiness surrounding things rather than a thing in itself, and so does not participate easily in the processes by which entities are identified and named by human minds. If we try to say that 'space' is a universal term for the many individual spaces which we experience, in the same sense that 'bird' is a universal term for an unimaginable number of individuals birds, we find that the individual 'spaces' referred to seem not to be well-defined entities with with recognisable shapes, but emptinesses with arbitrarily many shapes and sizes, sometimes (as in the urban case) continuous rather than discrete, and often lacking any property in common. We cannot easily *indicate* the spaces that we seek to express through this universal, as we can indicate instance of 'bird'.

Second, even if we are inclined to accept the existence of space, there is still a question of whether it really is an independent entity. As architecture reminds us, the creation of order in space depends almost entirely on how we deploy physical elements, such as boundaries and walls. How can an entity be of independent interest if its form, and even its very existence, seems to depend on something else. It was this apparent inseparability of space and form that led writers like Roger Scruton to regard the concept of space as an architectural delusion: space in a field, he argued, is the same as the space in the cathedral built in that field; all that has changed are the physical elements. There is, he concluded, no *space in itself*. (Scruton 1979)

Most architects would prefer to reject Scruton's conclusion, but much of the talk about space in the twentieth century adopted his position by default. For example, the routine architectural definition of space as *enclosure*, has the effect of reducing space to the physical elements that create it. As an entity in itself, it becomes invisible. It also distracts attention from the *relatedness* of space, which everyday intuition suggests is at the heart of architectural and urban space, and redefines it as a purely local phenomenon.[1] But even Tschumi's far more sophisticated account of space concedes important ground to Scruton by arguing that space is nothing without human activity to give it meaning, one instance perhaps of the attempt to conceoptualise our intuitions about space leading to the denial of space as an independent entity. (Tschumi 1996)

Space and spatiality

The same difficulty in addressing space as it presents itself to our intuition is found outside architecture. In the final quarter of the twentieth century, space came to the fore as a major theme in the social and human sciences as part of an attempt to bring these sciences closer to the materiality of everyday life. But in most cases, the difficulty of talking about the real space of experience showed itself as a pervasive tendency to reduce space to the *spatiality* of some process or agency, and so present it as an abstraction rather than a a directly experienced phenomenon. Theories such as 'human territoriality' (Newman 1972) or 'personal space' (Sommer 1969), for example, tied space to biological or socio-cultural drives in individuals (ref), and so again diverted attention from its real cultural manifestation of space as complex patterns 'out there' embodying social ideas, in favour of a view of space as the *spatiality* of a biological or cultural process. Even the sociologist Anthony Giddens, who proposed that space and time should be bought to the centre of social theory, made it clear that space was not of interest in itself, but acquired relevance only insofar as it reflected the spatiality of social processes. (Giddens 1984) In this, Giddens was reflecting the much older treatment of space in mathematical geography, which from the mid-nineteenth century saw the spatial form of the city as the system of locations, densities and distances produced as the spatial output of economic and social processes, rather than as a substantive pattern of interest in itself, so once again preferring *spatiality* to space itself.[2]

The effect of this preference for spatiality over space in the social sciences has meant that the social sciences simply do not address space in its primary experiential and form as the real patterns of space which confront us in the real world of everyday life. The problem of space at the start of the twentieth century seems then to be that in spite of the apparently huge and diverse range of theoretical ideas and paradigms that are used to talk about space, it is rarely *space itself* that is addressed, in the sense of the space we encounter in the world we live in, but the *reduction of space to* the spatiality of some other agency or process. As a result, space becomes nebulous and ill-defined. It might not be an exaggeration to say that the whole enquiry into 'society and space' would seem to be undermined by the undeclared assumption that space is already and only a by-product of society, since that dissolves the spaces in which we live and work into the abstractions of spatiality. But in architecture and urban design, it is exactly the precise nature of *real space* that is at issue. So we find a disjunction between spatial discourses and the problem of space as it must be addressed in architecture and urban design.

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[1] An account of how the concept of space as enclosure led to the fragmentation of space in some strands of modernism can be found in Hillier 1988 and Hillier 1996, Ch 11.

[2] For an excellent summary see Wilson 2000, though this is now changing as work refocuses on the idea of *network* and sees the morphology of the network as of interest in itself (Hillier 2005)

How then can space as a phenomenon *in itself* be approached? We have already said that the heart of the problem of space is in its *relatedness*. Architectural and urban space seems quintessentially to be composed of relational patterns – and relations have always been a puzzle to philosophers, because the relations between things do not seem to exist in the same sense that the things themselves exist, so the temptation is to see relations a mental constructs. But if we do this, we are in effect reducing space to a kind of *mental spatiality*. Where then should we looks for concepts of space as *relatedness*? We do not need to look far. Natural language sees space in this way. All languages have spatial terms which, and are purely relational, in the sense that they describe relations between two or three entities, which need not be named, since each can be any entity. For example, the prepositions of the English language, such as ‘between’, ‘inside’ or ‘beyond’ give very precise descriptions of the relations between three entities (‘the garden is beyond the wall’ implies that we are in a space ‘this side’ of both garden and wall, and so in a space distinct from both), whatever those entities might be. Our unselfconscious use of language means that in everyday life we routinely use the relational spatial concepts to represent and interpret the world. These relational spatial terms built into language are thought by many cognitive scientists to be foundational to the whole ability of language to express thought about the world, both directly and by metaphorical extension (in the sense that we might say ‘the adjoint functor theorem is *beyond* me, so please go *through* it again so I can get my head *around* it’). (see for example Bloom et al 1996, Lakoff & Johnson 1999)

But, surprisingly perhaps in view of the spatial precision of preposition-like terms, languages completely lack precise terms for the more complex systems of related spaces that we ordinarily find at the architectural or urban scale. This is the fundamental problem of real space, and it is this problem that space syntax addresses. Space syntax seeks to extend commonsense intuitive view of space as relations, as embodied in language, to the far more complex spaces that we routinely create and seem to understand through architecture and urban design, by making these complexes of spatial relations explicit rather than implicit. (Hillier & Hanson 1984) In this way, space syntax seeks to address the problem of space as it is found at the start of the twenty first century. The key difference between it and other approaches to space is that space syntax seeks first of all to address space *as relatedness, and as it is, and might be, created by buildings and cities,* and as it is experienced by the people who use them. It is not that it is not interested in the spatiality of social processes, but it sets out from the idea that the most powerful evidence for spatiality must be the ways in which human beings actually organise and arrange real space. Space syntax then begins by studying the phenomenon of space as it is found in the real world, and from this works towards an understanding of the spatiality of human activity.

In what follows we first explain space syntax and how it can be used in general research and design. We then explain the theory of the city as a *self-organising* system which has arisen from syntactic research on cities. Finally, we draw a number of theoretical conclusions about the implications of space syntax for architectural and urban theory and practice.

Foundations of space syntax

So what is space syntax, and how does it work? First, we need some foundations. Space syntax is a theory and a set of methods about space built on two ideas which reflect both the objectivity of space and our intuitive engagement with it.

The first is that we have to learn to think of space not as the *background* to human activity, as we think of it as the background to objects, but as an *intrinsic* aspect of everything human beings do - *Figure 1* - in the sense that moving through space, interacting with other people in space, or even just seeing ambient space from a point in it have a *natural and necessary spatial geometry*: movement is essentially a *linear* activity, interaction requires a *convex* space in which all points can see all others, from any point in space we see a variably shaped visual field we call an *isovist*, and it is by accumulating these as we move through the complex patterns of space we find in buildings and cities that we somehow build an enduring picture of the pattern of space as a whole.

Each of these geometric ideas describes some aspect of how we use or experience space, and for this reason how buildings and cities are organised in terms of these geometric ideas is a vital aspect of how we create them, use them and understand them. For example, space in cities is for the most part linear – streets, boulevards, avenues, alleys and so on are all linear concepts - with occasional convex elements we call squares or public open spaces, and the functioning of these spaces turns our to be strongly affected by their isovist properties. So the language of city space is written in this geometric language reflecting human behaviour and experience.

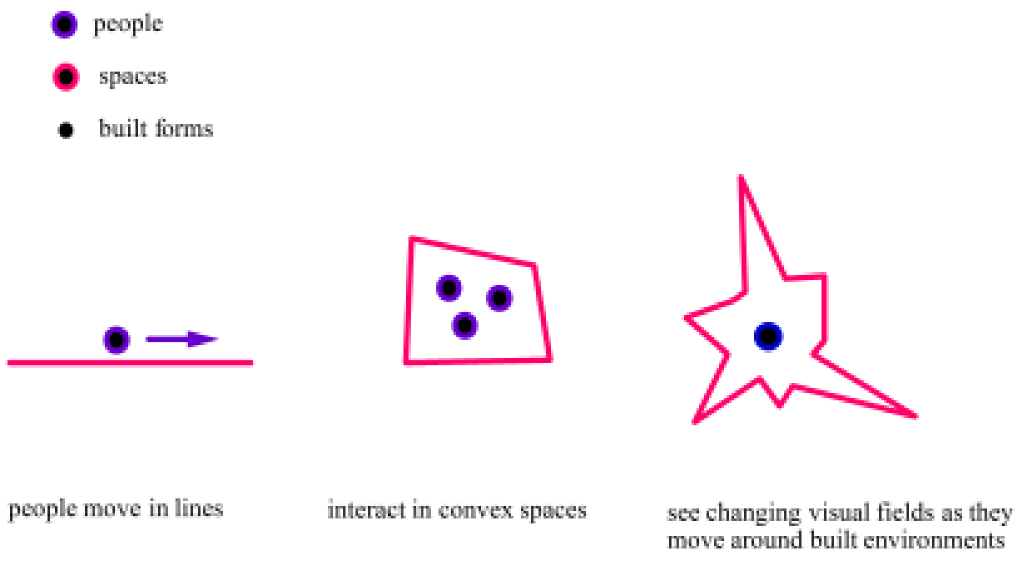


Figure 1 Space is not a background to activity, but an intrinsic aspect of it

The second spatial idea is that human space is not just about the properties of individual spaces, but about the inter-relations between the many spaces that make up a the spatial layout of a building or a city as a whole. We call this the *configuration* of space, meaning the *simultaneously existing* relations amongst the parts which make up the whole. This is what language does, but only referring to two or three relations at a time. But human beings routinely create these more complex patterns, and equally routinely seem to understand and use them, even through language cannot describe them. We infer from this human beings understand complex spatial patterns intuitively, even though they cannot describe or analyse them linguistically, and that this is likely to be because, as with language where we do not think about the syntax while we are using it, the relatedness of things forms part of the apparatus we think *with*, rather than what we think *of*. This is why we understand patterns better intuitively than consciously.

Insofar as it is a mathematical theory, space syntax seeks to formulate mathematically the configurational properties of space that we intuit, as manifested in the way in which we construct real spatial patterns through buildings and cities. You could say that by studying real space, we aim to reconstruct the human *language of space*, just as a linguist tries to understand the principles of natural language by studying language. In space syntax, configuration means not simply adding up the relations between pairs of spaces, but trying to give a picture of how a whole complex of relations affect each other.

The key to this is that a spatial layout not only *looks* but *is* different when seen from different points of view in the layout. We can make this visually clear by taking the layout in *Figure 2*, and drawing *justified graphs* (in which each circle is a room and each linking line a door) from spaces 5 and 10 to show what the pattern of space looks like from each. The two graphs from space 5 (left) and 10 (right) look quite different, in that one is shallow and the other deep, but are of course the same graph looked at from different points of view. But although different, each graph gives the real picture of what the whole layout looks like from that space, and thus express a real property of the layout.

The shape of the graphs can then be used to assign numerical values to each space, for example, to the degree to which we must pass *through* other spaces to go from each space to all others. This will be high or low according to whether we have a shallow graph, as on the left, or a deep graph, as on the right. To the degree that the graph from a space is *shallow* we say it is *integrated*, and to the degree that it is *deep*, segregated. So we can describe each space numerically in terms of how it relates to all the others. Such measure then are of *'configuration'*. (For mathematical details, see Hillier & Hanson 1984)

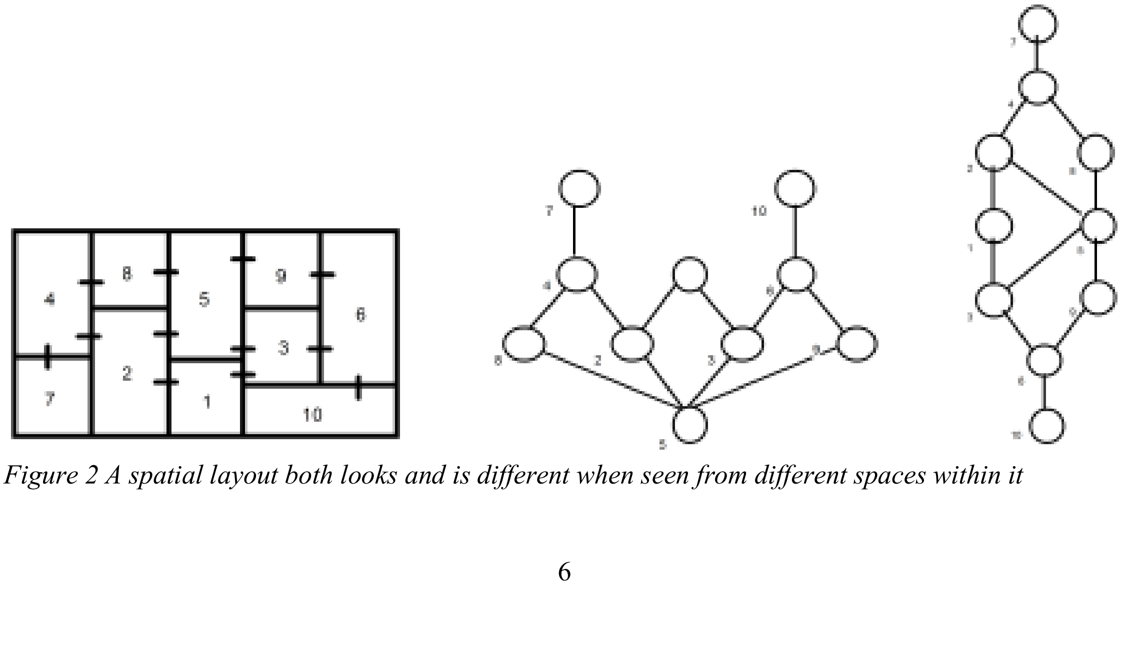


Figure 2 A spatial layout both looks and is different when seen from different spaces within it

Space syntax is about applying *configurational* measures to the patterns of different *geometric elements* that are created by buildings and cities. Whether we choose lines, convex spaces, isovists or even points as the elements for our analysis depends in what aspect of functionality we are investigating. For example, we find that when trying to understand movement in cities, line representations are most powerful (see below).

Making buildings speak

By looking at space in this way, we can begin to see both how social and cultural patterns are *imprinted* in spatial layouts, and how spatial layouts *affect* the functioning of buildings and cities. For example, at the simplest level, we can show how cultural differences are expressed through the layout of rooms in domestic space. For example, if we take the farm house in *Figure 3*, we find the *salle commune* (the space of everyday living and reception of informal visitors) is the most integrated internal space and the *grande salle* for formal receptions the second most segregated, after the 'bureau' of the male owner. We also find that the *salle commune* lies on all rings of circulation, so that if you remove it, the layout becomes virtually a single sequence of spaces. This is not always the case in French houses with *'salles communes'*. Sometime a transition space - say a hallway or corridor - is the most integrated space, and where this is so, the salle commune loses is dominant spatial role. Our studies suggest that this may be to do with gender roles. (Hillier, Hanson & Graham 1987, Hanson 1999) This is one example of the ways in which spatial configuration is shaped by culture. In general, to the degree that the order of integration values for different activities in the house is in the same or a different *order*, we can see evidence of cultural commonalities or differences across a sample. So what we are seeing is the constructive effect of society and culture on spatial patterning.

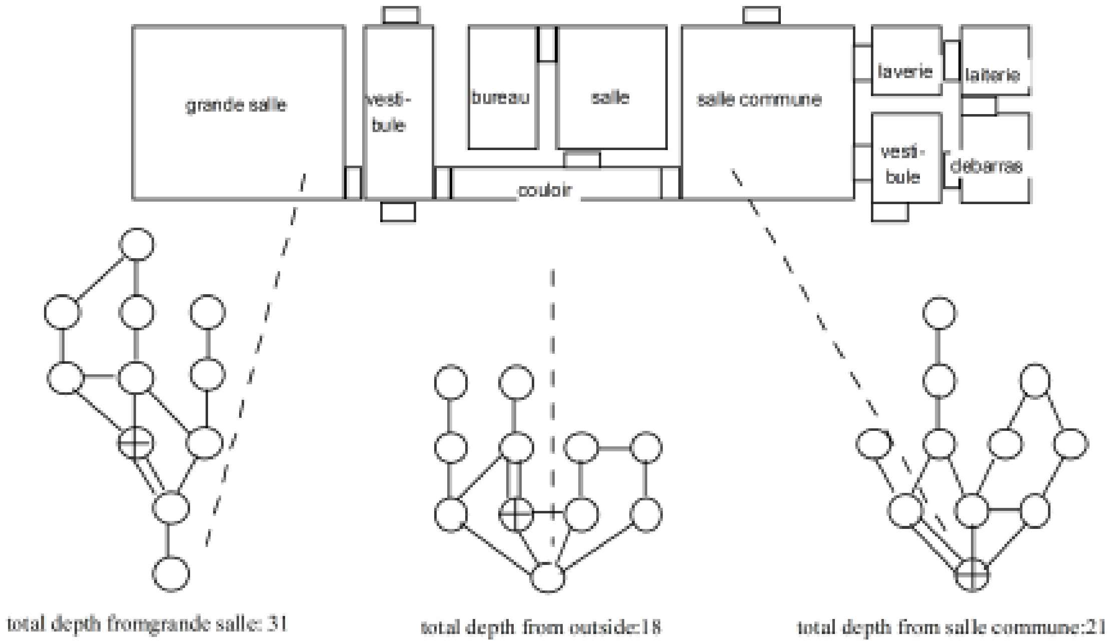


Figure 3 The layout of a house looks more or less integrated from different points of view

We can show the patterns *visually* by using colours to index numerical values, always using red for the most integrated thought to dark blue for least:

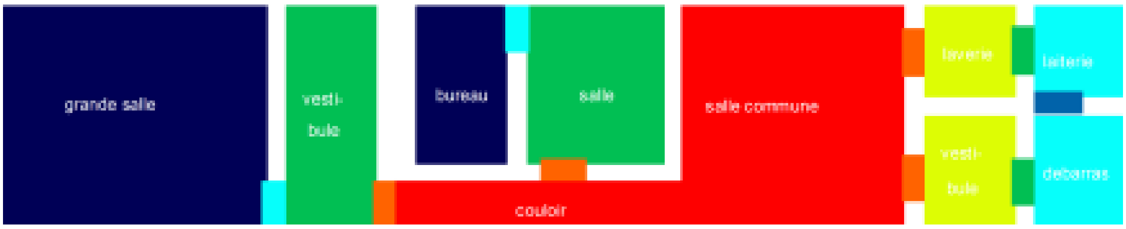


Figure 4 By assigning colours to integration values we can intuitively see the numerical pattern

This is a vital aspect of space syntax research, since it allows us to search for patterns visually, and therefore intuitively, as well as using simple mathematics.

We can also use space syntax to investigate the *effect* of spatial layout on functioning. In *Figure 5*, we show on the left traces of 100 people entering the Tate Britain gallery in London and moving about for ten minutes. On the right is a configurational analysis of all the visual fields from every point in the Tate plan. Technically, it draws the visual field from each point of a fine tessellation filling the plan, overlaps these so that an overlap counts as a connection, and calculates how many visual fields you need to use to get to see the whole gallery from any point within it. Again, the red locations are the most visually integrated, through to blue for the least. It is easy to see that the movement and space patterns resemble each other as patterns quite closely.

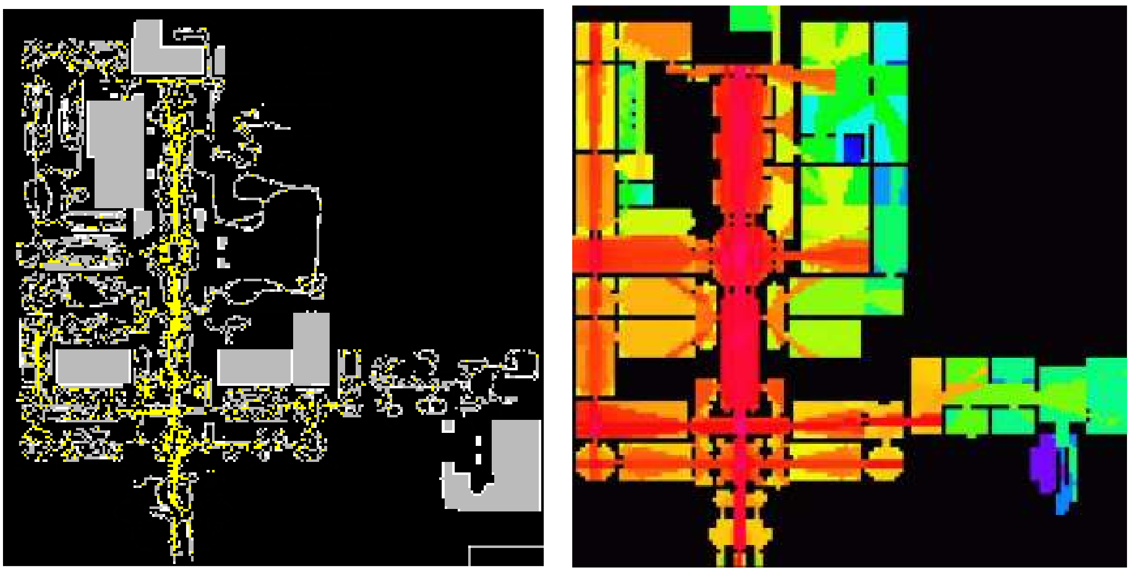


Figure 5 First ten minute movement traces (left) and visual integration analysis (right) of Tate Britain

We can check this statistically. It turns out that about 68% of the differences in movement rates in rooms can be accounted for by the visual field structure, implying that people are using the space structure of the Gallery, rather than, say, the attractive powers of particular exhibits, to guide them around the gallery. (Hillier et al 1996)

Once we understand of the relationship between the structure and functioning of the gallery, we can use the spatial model as a powerful design tool (as is now happening) by simulating the effect of, for example, extending the Gallery in different ways (*Figure 6*):

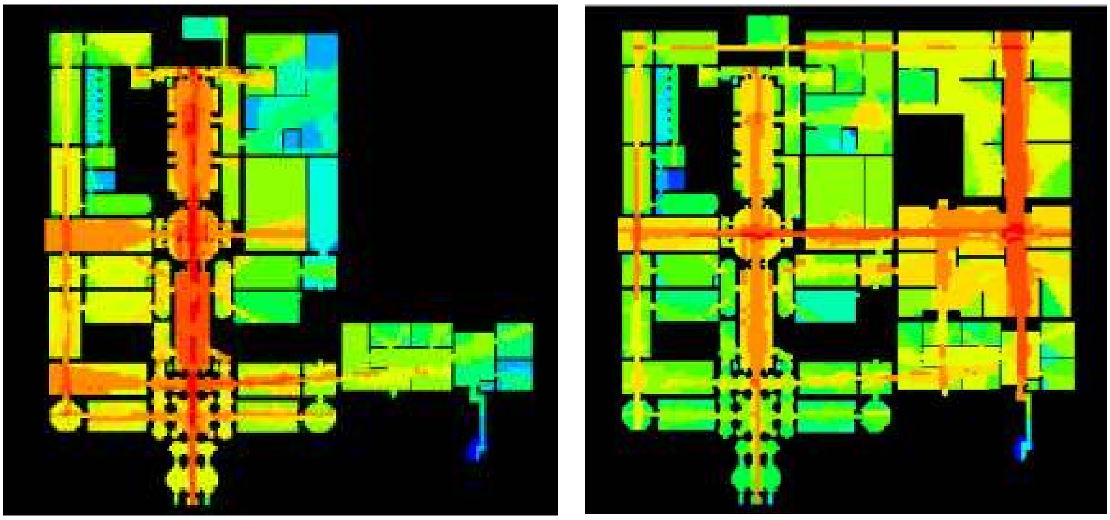


Figure 6 Using the analysis to simulate the likely functional effects of design changes

This illustrates one of the great advantages of space syntax models: the model that is used for research can be used, without modification, for design experimentation and simulation.

This then is how space syntax works. By an analysing space rigorously, and observing human activity carefully, we can show that space and social activity relate in two ways:
 - a spatial layout can *reflect* and *embody* a social pattern, as in the case of the French house, where space was laid out and categorised to give reality to a culturally given pattern of activity, and so reinforce and reproduce it. So we can perpetuate things about ourselves and our cultures by building them into space, and so making them seem inevitable and natural. Culture, after all, is what appears natural to us, and the way to reproduce it is to embed it in everyday life.

 - but space can also *shape* a social pattern, as in the case of the movement study, since by shaping movement, space also creates a pattern of natural co-presence in space. Although in the not too distant past, social theorists saw society beginning with human interaction, co-presence is now increasingly seen to be a significant social resource in itself. I will show this is the case, and that the ability of space to shape co-presence through movement is one of the keys to how collections of buildings become living cities.

Another way of saying this is that space can be used both in a *conservative* mode to structure and reproduce existing social relations and statuses, usually by using space to segregate, and in a *generative* mode to create the potential for new relations by using space to create co-presence through integration. The conservative mode leaves things as they are, the generative mode leads to morphogenesis and the appearance of new structures and patterns. This duality will turn out to be of critical importance in understanding the forms of cities.

Space syntax is then both a tool for understanding buildings by rigorous analysis, and an aid to designing them by using spatial analysis and representation. We suggest that this implies a re-balancing of our conceptions of art and science and how they relate. In one sense, space syntax aims to become a science with all the theoretical and empirical rigour that that implies. On the other hand its see itself as in the service of the art of design, and to this end it sees one of its fundamental role is expressing spatial complexity in ways which access it to design intuition, for example by the simple procedure of using colours to represent patterns of numbers. Nowhere is this clearer than in the space syntax approach to the city, to which we now turn.

Understanding the city

In terms of the city, space syntax sees itself as part of the emerging sciences of *networks.* In the past, most attempts to understand the city scientifically have not seen the city's most obvious network - its street network – as being of scientific relevance or interest. But it is the street network that links the aggregations of buildings into a single system, it is what you *see* when you look down on a city, and it is what you *navigate* when you walk or drive in a city. In all these senses, the street network seems to be the common ground between the real space of the city and our experience of it. Space syntax allows us to approach this key network in a new and original way, and in doing so to discover important principles about how cities are structured spatially, how they work, and how they grow and change.

But why should the network be interesting? After all, many, including Camillo Sitte (Sitte 1889), have thought it was not. The answer is that syntactic studies of cities as networks of space have, in recent years, brought to light a fundamental link between the structure and functioning of cities: that the *configuration of the network is, in and of itself, the primary shaper of the pattern of movement.* In shaping movement, it also shapes the patterns of human co-presence - and of course *co-absence* – that seems to be the key to our sense that good cities are human and social things as well as physical things. This is a far reaching proposition, and, if true, as increasing evidence suggests it is, it has far reaching implication for how we think about cities and design them. The large scale *architecture* of city space, which has been neglected for decades, matters much more than we thought to the life of the city and how it comes into existence.

In principle, this idea is not really new. Most designers believe that we can manipulate space to create the emergent human patterns that are the source of our sense that cities are civilised, safe and pleasurable, although there are conflicting view on how this can and should be done. What is new is the idea that this is a *scientific proposition*. The idea does not feature significantly, for example, in most engineering based movement models, where movement is seen as a matter of *attraction*: locations attract movement according to the 'mass' of their attractions, such as the shopping floor area, and the network is the means of getting there. This focus on locations rather than networks was necessary to allow modellers to use the newtonian equations that underlie the maths: that attraction is proportionate to combined mass of bodies and inverse to distance. But is has been this sidelining of the architecture of the grid, in favour of the abstraction of attraction, that puts attraction based movement models at one step removed from the architecture of the grid itself and from the preoccupations of designers.

This is not, of course, to deny attraction. It is commonsense. People make trips because the shops are there. But it is not fundamental. If we are right that the space network itself shapes movement, then the shops are where they are because they are following the patterns of movement already created by the network. So we can not start with attraction if we want to understand this city. We should start with the network which creates the pattern of attraction. So the network view of the city is also a *paradigm change*. It puts everything in the city in a different order.

Once we understand the relation between the network configuration and movement, we can begin to see how cities come to be as they are and how they work. In particular, we can begin to understand why and how cities self-organise into a *polycentric* pattern, by creating a networks of centres and sub-centres, at all scales, from a couple of shops and a cafe to towns within cities and even whole sub-cities, set into a background of residential space. This is the nature of the organic city which evolves over tens or hundreds of years to form the seamless web of busy and quiet places, with everything seeming to be in the right place. So what we are talking about here is a theory of the organic city. A key element in this will be that the process by which cities create themselves is about the *relation between scales*: that how local places arise in cities depends as much on how it is embedded in its larger scale context as in its intrinsic properties. In fact, it will be argued that this is true of space in general, and that the *local-global relation* has featured too little in our attempts to reproduce the excellencies of cities through design.

Space shapes movement

As my argument is built on the foundation of the link between space configuration and movement, I must first convince you that it is the case. Let me begin by trying to show you it is commonsense. Consider the simple grid in *Figure 7a*, with a main street, cross street, side streets and backstreets. Imagine that all the streets are lined with houses, and people are moving between the houses by the most direct routes they can find:

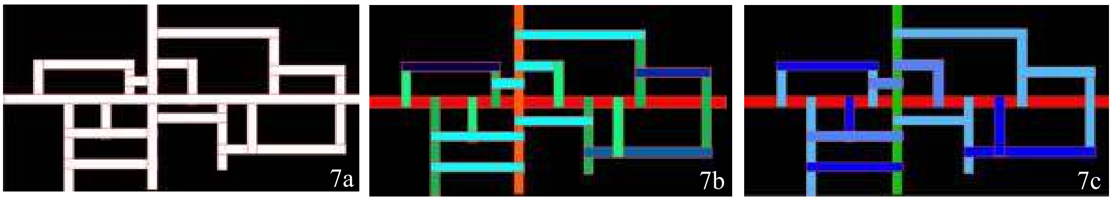


Figure 7a A notional grid with a horizontal main street, vertical cross street, side streets and back street
Figure 7b Notional grid: pattern of 'integration' values, or the closeness of each line to all others, from red for highest through to blue for least
Figure 7c Notional grid: pattern of 'choice' values, or the degree to which each line lies on simplest paths from each line to all others, from red for highest through to blue for least

Several things are intuitively clear: More people will pass through the main street than the side streets or back streets. More people will pass through the central bits of the main street than the peripheral bits. The main street is easier to get to than other streets - it is more accessible. The cross street will also get a good deal of movement - but more than the main street? it is hard to be sure. What is clear is that we intuitively expect the position of each street in the overall grid to affect both to- and through- movement patterns flows. It is not a matter of psychology, but to do with the way the grid is put together.

Can we measure this? Easily. In fact these are well-known properties of networks. In any network that can be represented as a graph of elements and relations, it is easy to calculate the *closeness* of each element to all others, that is the accessibility for *to-movement*, and the degree to which each element lies on paths *between* elements, that is, its potential for *through-movement*. The closeness of each element to all others is in fact the *integration value* of a space as previously defined, and we can colour as before from red for high integration through to blue for low, as in *Figure 7b* where we apply it to the streets of our notional grid. The *betweenness* property, that is the propensity of spaces to lie on paths between pairs of elements we have always called the *choice* value, meaning how likely it is to be chosen on paths from all elements to all others, and colour up as before from red for high through to blue for low, as in *Figure 7c* Again by using colours for numbers we can *see* the pattern. Traffic engineers are familiar with both of these measures, but they have never to my knowledge applied them to the street networks considered as geometric configurations in their own right, that is they never considered them *architecturally.*

Now all this is true of all urban street networks, however large or complex. In fact, it is necessarily true of networks in general, and the mathematical reasons why we should expect this to be the case are explained in (Hillier & Iida 2005). The question for cities is: what geometrical elements should we apply the measures to, and how do we calculate distance? There are no obvious geometrical elements in cities because space is by definition continuous, without boundaries. Intersections, as used by traffic engineers, are an obvious candidate, but intersections do not capture the geometry of the city. Geometrically, street systems are essentially networks of linear spaces. We move along one line, then change direction and start moving along another. Also, we mentally construct the relation of origin and destination for trips as a notional line, and then try to approximate this through the available linear structure of the grid. One way to capture this would be to represent the street network simply as a network, extending each as far as it can without a change of direction. In effect, we expressing the street network as the longest and fewest lines that can cover all the space and make all connections. This can be done by algorithmically (Turner et al 2005), but researcher tend to learn more about the city by digitizing the lines by hand.

Once we have this line network, we can calculate, say, the *integration* value of each line in relation to all others, and colour up as usual. In effect, we are measuring how many turns we have to make to go from each line to all the others, a kind of *complexity distance*. We can also place a limiting radius on the measure, by only counting the complexity distance up to a given number of turns from each line. In *Figure 8* the radius is 3, counting the root line as 1, and we call this *local integration*, in contrast to *global integration* if we set no radius, or a high radius.

Figure 8 Part of central London, with an axial maps superimposed coloured up for 'local integration', that is the closeness of each line to all others up to two turns away from each line

Remembering that red is most integrated and blue least, as soon as we do this, the pattern brought to light by the colours in *Figure 8* is very striking. The red east west line is Oxford Street, London's main shopping street, and overall the pattern formed by the red, orange and yellow lines conforms to a remarkable degree to our intuitive idea of how London is structured.

But is it really a meaningful picture. We can test this by observing flows along lines and comparing the numbers to the integration (or complexity distance) values: do we find that more integration means more movement. We took five separate areas of London, observed pedestrian and vehicular flows in around100 street segments in each area, and correlated the flows with different configurational measures for each street.

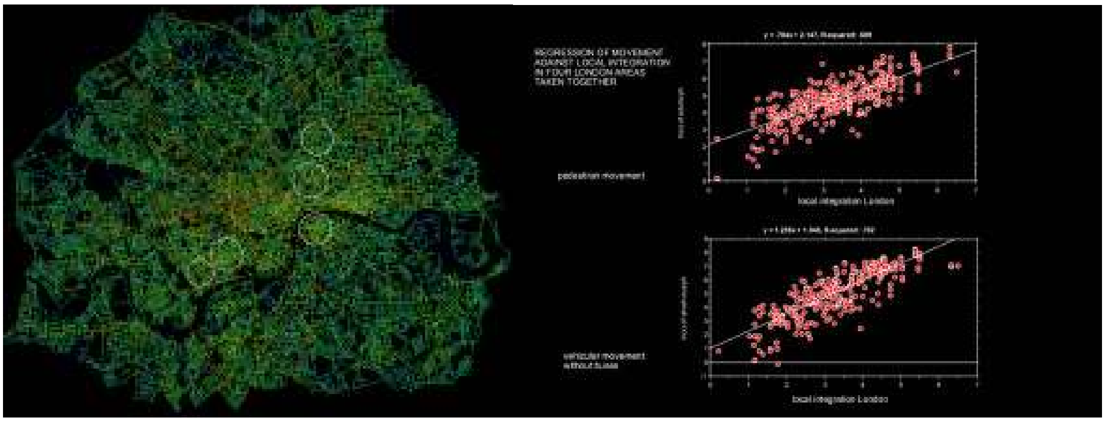


Figure 9 (left) An analysed axial maps of London within the North and South Circular Roads, coloured up for local integration with five selected areas within which observations of vehicular and pedestrians flows were made throughout the working day
Figure 9 (right) Regression of local integration against vehicular and pedestrian movement rates is all five areas taken together showing that the street network configuration accounts for about 70% of vehicular movement and 60% of pedestrian movement

Again, the results, to say the least, striking The degree of correlation between vehicular flows and radius 3 integration is over .7, and for pedestrian about .6. This means 70% of the differences in vehicular movement flows, and 60% of pedestrian are due to the pattern of the street network itself, not measured as a pattern of metric distance, but as complexity distances. If we want to improve the correlation, we can of course add the others factors in: numbers of shops, closeness to transport nodes, and so on. But what is really important for design here is that we have found a powerful relation between the *architecture* of the urban grid as a purely geometric object, without any reference to land use.

The discovery that the spatial integration pattern of the street network shapes movement is more important that perfect prediction. It puts us in a position to design space for movement, and then assign the land uses to the right places according to their need to be close to movement. And because our models are *architectural*, in the sense that they are based on a representation of the real geometry and connectedness of the urban street network, we can again use *the same model that we use to analyse the city for design.* All we need to do is model the area, observe it to make sure our model if working, and then sketch in our design fir the site to see that it does to the spatial patterns that produces the movement.

Figures 10 and 11 Using syntax in sketch design by analysing the area around a site and then adding candidate designs and reanalysing. Figure 10 shows that a grid-like scheme would be segregated from the surrounding area, while Figure 11 shows that a scheme which extends key local alignments into the site could create a focus of integration within the site.

We have a design tool, one which can and should be used right at the earliest stages of design. *Figure 12 and 13 shows* the impact on design. 12 is the design for the Kings Cross Railway Lands site in London before the intervention of syntax working with Norman Foster, and 13 is the syntax informed Foster scheme (Hillier 1993).

Figure 12, the SOM scheme proposed for the Kings Cross Railway Lands site in London before the intervention of syntax working with Norman Foster, and Figure 13 the syntax informed Foster scheme. Neither were realised as the project to develop the site was abandoned in the severe economic recession of the early nineties.

Syntax Mark 2

This is space syntax Mark1, as has been used on hundreds of urban analyses and projects (see for example www.spacesyntax.com). Mark 2 is much more precise. It works at the level of the *line segment*, rather than the whole line, and connections between segments can be weighted for metric distance, or the angle of change, as well as for complexity distance. So we can give different interpretations of the same grid, and for both the to-movement (top) and through-movement (bottom) measures.

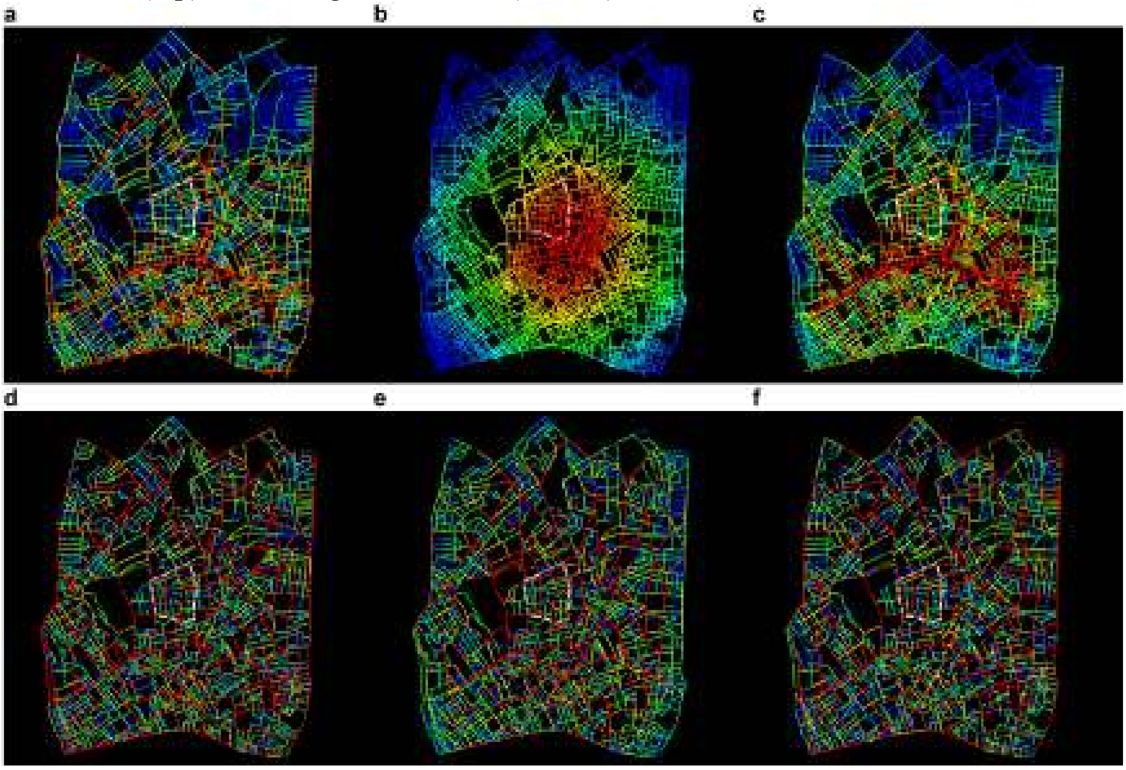


Figure 14 Different interpretations of the same urban grid using different definitions of distance from each 'street segment' (between junctions) to all others: on the left, the 'least angle change', or geometrical, interpretation of integration (above) and choice (below), in the centre the 'shortest paths' or metric interpretation, and on the right 'fewest turns' or topological interpretation

The two images on the left give a *least angular change* measure for integration (above) and choice (below), the two in the centre orthodox *shortest paths,* and those on the right *fewest turns.* So we can now ask: which version of the numbers correlates best with real movement. The answer is that *least angle* paths is best and metrically *shortest paths* the worst. The only plausible interpretation of this result that people do not navigate with a mental model of distances, but with a geometric mental model of connectivities. As cognitive scientists have long suspected, but been unable to prove, we navigate with an *architectural* model in our heads, not a simple account of distances. Again, this has major implications for how we design cities.

Using the Mark 2 model we an also explore radius effects more powerfully. By setting set a series of different limits on the *radius* around each segment within which the measures for the segment are calculated - say 300 yards, or half a mile, or five miles, we can reflect how people might read street network in different ways for different lengths of trip. For example, if we are driving right across a whole city, we will tend to read the network in terms of the main roads, perhaps with a few short cuts and ‘rat runs’. But if we are walking to see aunt Hilda a half a mile away - it still happens in the UK - we read the network in terms of its small scale structure.

But again by correlating the measure for the different radii with real movement rates, we can ask which correlates best, and so define the catchment area for each segment. What we find is that the correlation first rises as we increase the radius, and then stabilizes, showing we are not using information beyond a certain radius in calculating the properties of the network that are producing the flows. This will vary with area. So using this method we can find out a great deal about the properties of the street network which are producing the movement flows we see. But once we understand this basic relation between grid and movement, then we can turn our analysis round and use it to really begin to understand how cities are put together and how they come to be as they are.

The shape of cities

If the shape of the city shapes movement, then what is that shape like, and how does it come to be like that ? First we can use the analysis to show how cities acquire a certain type of large scale structure. For example, if we take a small town in France *Figure 15 and* represent its street structure as a simple line map and analyse its closeness pattern, colouring up from red to blue in the usual way, we find the red, orange and yellow lines - the main integrators, as we call them - form a striking pattern: a kind of *deformed wheel* : there is a *hub*, or at least an intersection, of integrated lines at or near the centre, integrated *spokes* which link centre to edge, and sometime also we find integrated *rims* of edge lines.

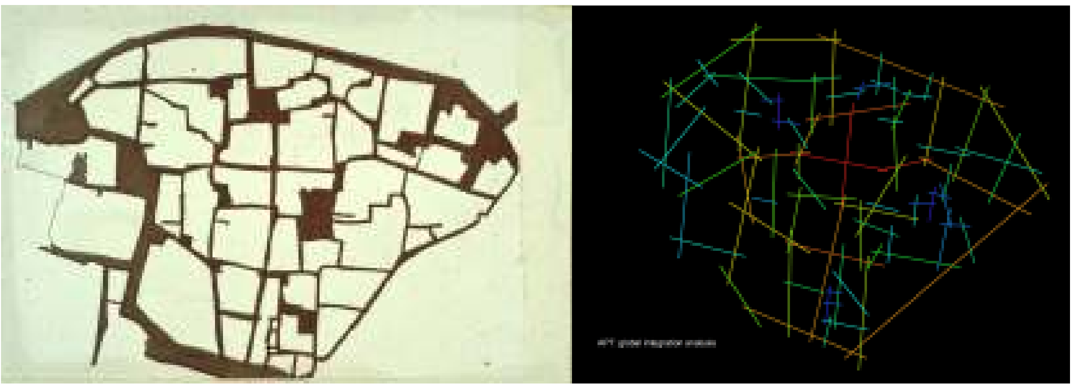


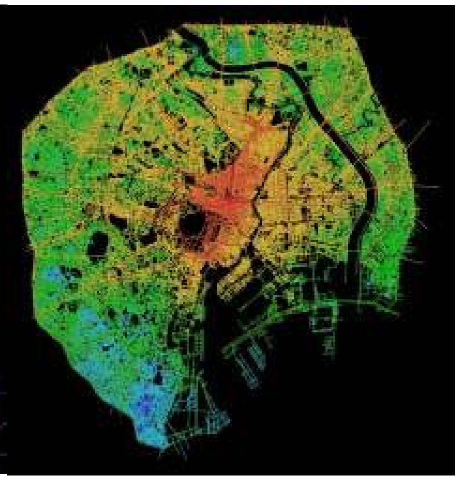
Figure 15 left *Plan of a small town in Southern France with the space in black and buildings in white*
Figure 15 right *Axial maps of the town analysed for global integration and showing the ‘deformed wheel’ pattern of integration through the distribution of red, orange and yellow colours*

The wheel forms the dominant pattern of public space, where most of the shops are, while the areas in the interstices are the more residential areas, though of course with gradations between the two. So this means that the structure is not purely formal matter. It has to do with what is going on in the social and economical life of the town.

Suppose we now take four cities or part cities from different parts of the world with very different geometries, from the most to least geometric: Atlanta, The Hague, Manchester and Shiraz, we find that each approximates the *deformed wheel* pattern.

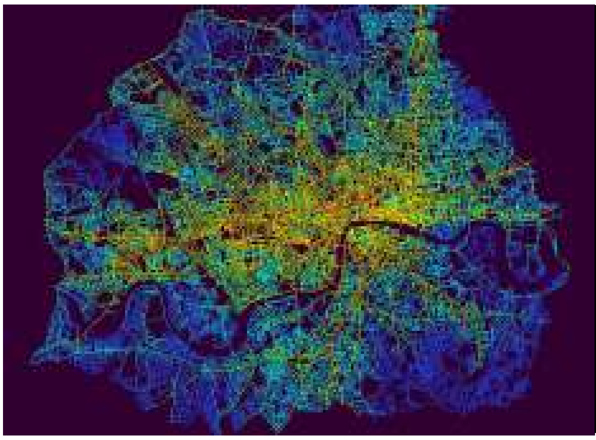
Figure 16 Analysed axial maps of four geometrically different cities in different parts of the world from the most to least geometric: Atlanta in the USA, The Hague in Holland, Manchester in the UK and Shiraz in Iran, showing that each approximates the deformed wheel pattern. Note that in these cases, the analysis is based on the geometric or 'least angle' interpretation of integration, though the simpler line analysis produces a similar result.

We find it the same kind of pattern in Venice, even without the canals, and we find it in a more developed form in Tokyo.



Figures 17 Analysed axial map of Venice without the canals, showing an underlying deformed wheel structure, in this case using the simple line analysis.
Figure 18 Analysed axial map of Tokyo showing the deformed wheel pattern with a series of rims linking the radials, again using the simple line analysis.

In cities like London we find the deformed wheel twice over, at the local as well as global level. This is why people think of London as a set of urban villages. It is not really a village. It's linkages to the supergrid are a key part of it. But it does give London its distinctive informal structure. London is a classic case or the relation between scales being the critical feature of urban space.



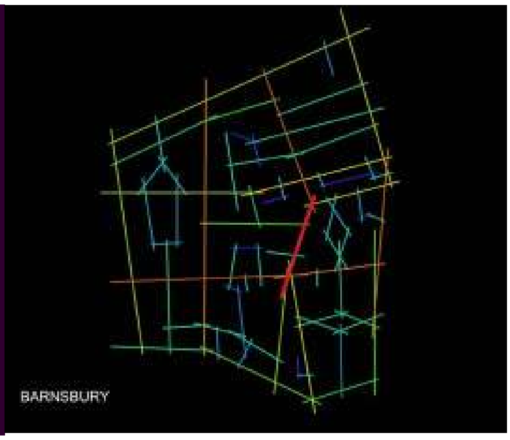


Figure 19 Analysed axial map of London showing the deformed wheel pattern using the 'least angle' analysis.
Figure 20 Analysed axial map of the Barnsbury area of London, using the simple line analysis, showing the deformed wheel pattern focused on the 'village line' and linking it to the larger scale grid in all directions.

Why the deformed wheel? The answer is simple. It is a way of overcoming the natural tendency for centres to become segregated as the city grows around them by linking centres to edges, so accessing strangers to the heart of the system and inhabitants to the edges. So this *deep structure* of the city is a *spatial* phenomenon, but one which is shaped by the city as a *social* thing.

The dual city

But we have generated a puzzle: if cities are geometrically very different, as they are, how do they come up with a similar generic global structure? The answer is that cities are created by a *dual* process, and each part of the duality exploits the relation between space and movement in a different way, reflecting the *generative* and *conservative* potentials of space we identified earlier. On the one *generative* side, there is a *public space* process which is about bringing people together, and which therefore orders space in such a way as to maximise the reach of spaces and so maximise movement and co-presence. This process is largely driven my *micro-economic* factors, and tends to be *invariant* across cultures as trade and exchange always work the same way. The public space process gives rise to the *global* structure of the city, usually some variant on the *deformed wheel*.

On the more *conservative* side there is a *residential space* process, which uses space to restrain and structure movement in the image of a residential culture of some kind, and how it seeks to structure relations between inhabitants and strangers, men and women, near and far kin, and so on. Domestic space and its environs is usually the richest expression of culture in space, and of course it is different across regions, and even within regions. This is why we find such great differences in the *fabric* of space - its geometry, its connectivity, its openness or closedness - in such contrast to the tendency of global structure towards universality.

We can illustrate this dual process with singular clarity in a city with more than one culture (now unfortunately separated): Nicosia in the island of Cyprus.

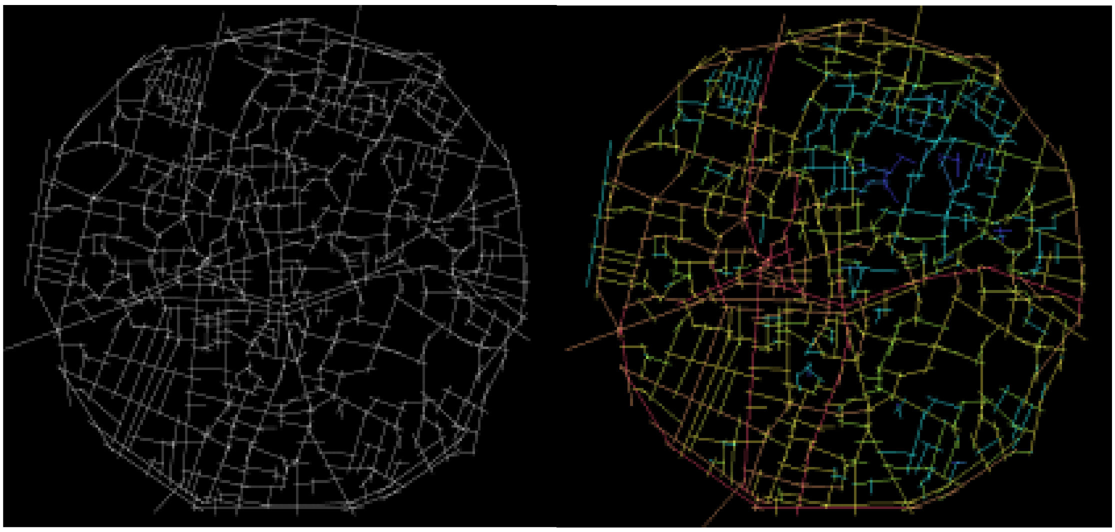


Figure 21a and b Figure 21a is an axial map of Nicosia within the old walls, showing the different geometric patterns of the Turkish (top and right) and Greek (bottom and left) areas. Figure 21b is the integration analysis showing how the geometric differences are reflected in syntactic differences

In Figure 21a, top right is the Turkish quarter, and bottom left the Greek quarter. Their line geometry is different. In the Turkish quarter, lines are shorter, their angles of incidence have a different range, and there is much less tendency for lines to pass through each other. The integration analysis in Figure 21b highlights even more how different the areas are. Syntactically, the Turkish area is much less integrated than the Greek area. We can also show that it is less intelligible, and has less synergy between the local and global aspects of space.

Yet in spite of these strong cultural differences in the *tissue* of space, we still find Nicosia as a whole is held together by a clear ‘deformed wheel’ structure. The deformed wheel, as it were, overrides the cultural differences in the residential fabric of space, and creates the global system of spaces where cultures come together. We need to understand both processes to design cities. Most of all, we need to know that the two processes are driven by the *same underlying laws* being used in different ways. In one way, to generate public space in which movement and co-presence is maximised. In the other to generate residential space which it is more controlled and modulated according the the needs of culture.

The polycentric city

So how, against thus dual background, do cities acquire their *polycentric* form, through the evolution of a network of linked, differently scale centres, set against the background of residential space? The deformed wheel accounts for some of them, but not others. The process is more intricate. In *Figure 22* we see the distribution of shops, restaurants and bars in part of north west London.

Figure 22 The distribution of shops and catering outlets in part of north-west London showing a polycentric patterns across a number of scales.

We see centres at all scales, and with a certain geometric logic to their scaling and spacing. How does it happen? It is hard to see with the naked eye, but you can explain about 72% of the differences in the scale of centres in terms of what we call *local grid conditions*, as measured by our local integration measure. What process creates this outcome? We can outline this in a series of generic stages:

·as cities grow through the accumulation of building and areas, a street network emerges which links it all together.[3]

·through its structure, the emergent street network shapes a pattern of 'natural movement', making some spaces higher in co-presence than others

·movement seeking land uses then migrate to movement-rich locations, while others, perhaps residential, tend to migrate to less movement rich location – if movement seeking land uses locate in the wrong locations, or if something changes the network, then they probably don't succeed – so there is a selection mechanism in our evolutionary process

·the presence of shops in locations that are already movement rich attract more movement, so there is a multiplier effect on the movement already there

·this then attract more, and more diverse land uses, which seek to take advantage of the enriched co-presence in the location

·this process will often stabilise at a certain level related to the original grid properties that generated the natural movement in the first place.

·But in other locations, again dependent on the strength of the original conditions that initiated the process, the growth of the centre feed back onto the structure of the grid – for example to subdivide blocks to improve inter-accessibility and to increase the quantity and diversity of the 'shopping surface'. We call this process *grid intensification.* It can be both the *cause* and the *effect* of centre formation.

This is the generic process. But the fact that it happens at different scale and involves different spatial properties makes it more complex. In general we can say that the emergence of centrality is about being close to movement and being close to the generators of movement, that is the residential units which make up the bulk of the city. This is the most local process, and it is metric, so let us look at it first.

Suppose there is a line of houses, what is the best location for a shop. The centre, because it is closest to all the others. But suppose the line of houses joins another at a T-junction. Then the intersection is closest, and we find the ubiquitous corner shop. Now there is more to the corner shop than meets the eye. Let me show you how by bringing in a bit of theory. In *Figure 23* we see four grid, with exactly equal land coverage, and so equal travellable distance, coloured up for the average metric distance from all points to all others, so redder mean closer to everywhere, bluer means farther, and so shorter or longer mean trips lengths. We can see the regular grid top left is fairly red from the centre out, but that when (top right) we move blocks to break the vertical lines, the average length of trip increases, and it does more so when we elongate some of the blocks as bottom right. But it is the bottom left that is interesting. If we reduce the size of the central blocks and compensate by increasing the size of the outer block to keep land coverage and total

[3] For more detail on how exactly this happens see Hillier 2001)

travellable distance the same, we find that it is a good deal more trip efficient than the regular grid. Now this is the way cities grow of course with smaller blocks at the centre and larger blocks towards the edge.

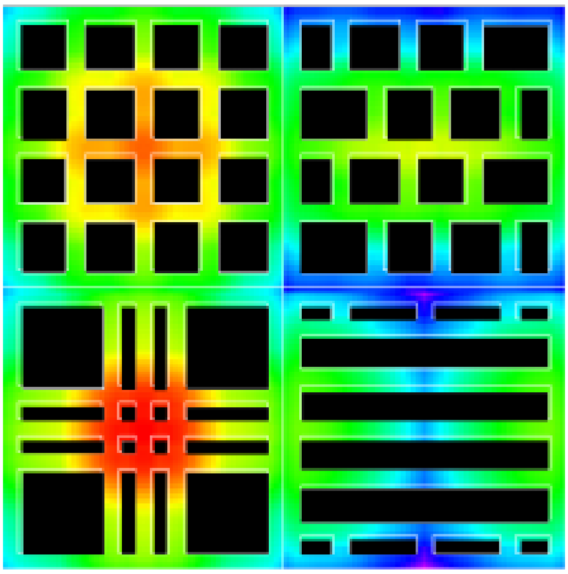


Figure 23 Four grids, with exactly equal land coverage, and so equal travellable distance, coloured up for the average metric distance from all points to all others, so redder mean closer to everywhere, bluer means farther, and so shorter or longer mean trips lengths. The grid (bottom left) with smaller central blocks compensated by larger edge blocks is has a shorter average trip length than the regular grid (top left)

But this has other implications. It means that when block size is small, you are closer to all the buildings that make up the block than when they are large. One of the seeds of centres is no more than this. The shops survive better when local blocks are small. This is one of the secrets, for example, of the little shopping streets that you often come across surprisingly in London.

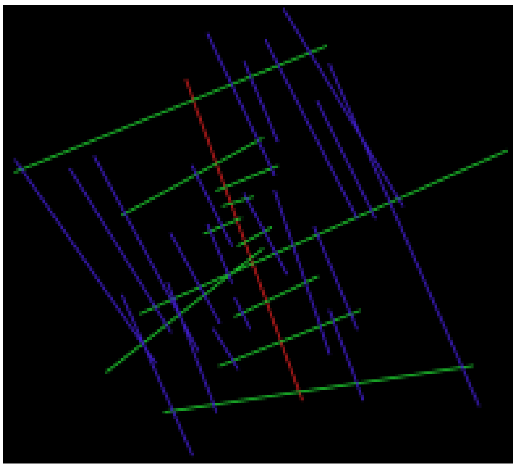


Figure 24 Lambs Conduit Street in central London, a typical local shopping street, with its smaller scale 'intensified' grid in its central parts.

You also find that if you take one of the long radials into London, it has three shopping high streets on it, with quieter stretches in between. *Figure 25* Where the shopping high streets are, the grid is markedly smaller than in the interstitial residential parts of the road.

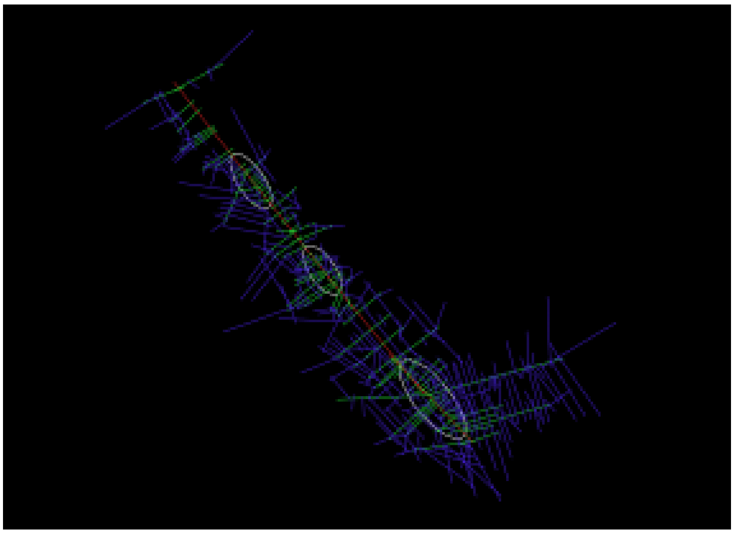


Figure 25 One of the long radials into London, with three shopping high streets circled, and quieter stretches in between. The shopping high streets have smaller scale ambient grids than the interstitial residential parts of the radial.

We also find that if you take a transect across a smaller city like York, showing the local grid conditions from the transect up to three steps away, you find the centre can be identified pure from the smaller scale and more regular block structure you find in the centre. Of course it is also in the nature of cities to start with small blocks and for block size to increase with greater distance from the centre.

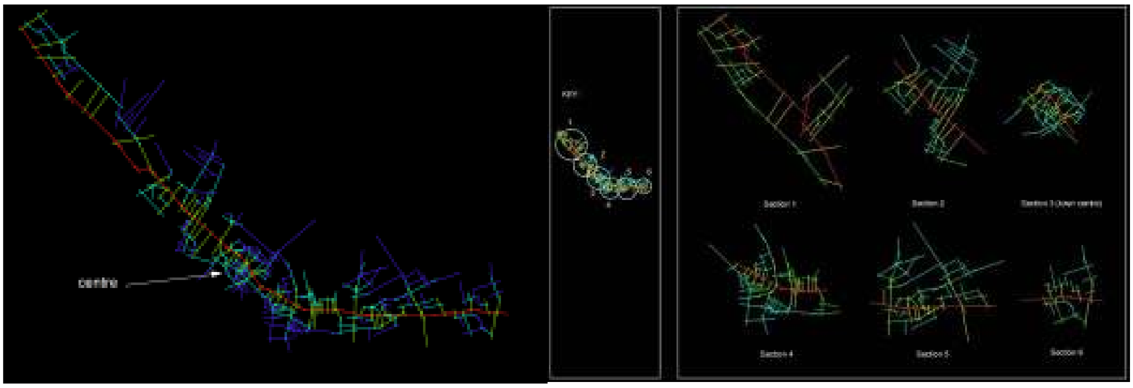
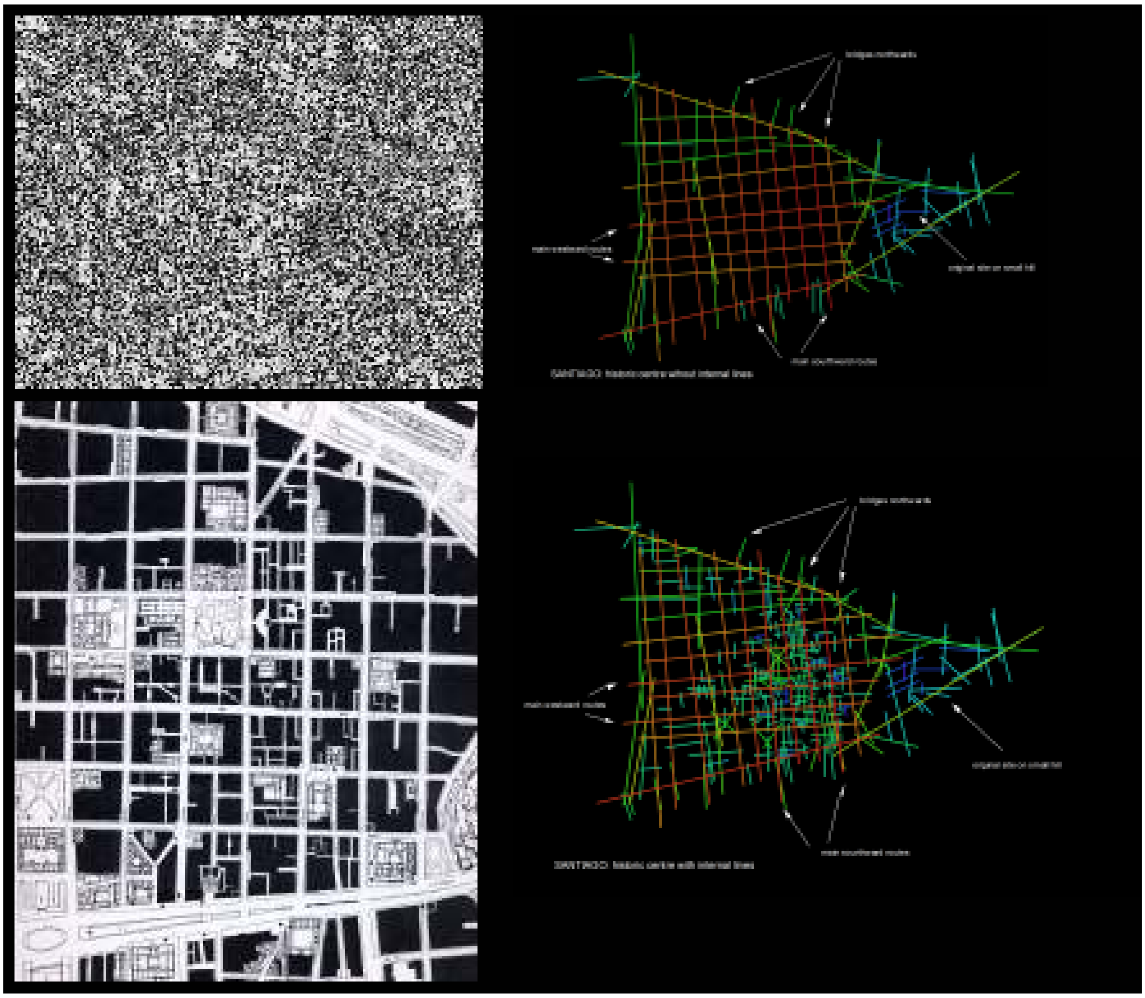


Figure 26 On the left, a 'transect' route (in red) across the axial map of the city of York, showing how the local grid conditions from the transect up to three steps away change as you move from edge to centre and out again. On the right, the sections of the transect show that the centre can be identified pure from its smaller scale and more regular block structure.

We call this phenomenon *grid intensifiation*. It can both initiate centre formation, as in the small London shopping streets, but it also happens as a centre develops to improve the interaccessibility of the interdependent facilities in the centre. A centre is *about* the idea that if you go to one thing can you get to the others. The process is beautifully illustrated in the evolution of the original Spanish grid for Santiago de Chile. *Figures 27-30* shows, with syntactic images the intensification of the original grid to create what is now a successful market area.



Figures 27 An aerial view of the old central area of Santiago (Chile), showing the original Spanish Grid
Figure 28 An analysed axial map of Figure 27
Figure 29 The central area of Santiago with the block interior structure of arcades and alleys as it has developed over the years, maximising inter-accessibility and shopping facades.
Figure 30 The axial map of Figure 29 including the block interiors, showing that grid intensification has developed within an envelope defined by the major route leading north, south and west, a classic case of how global and local factors combine in intensive market areas.

Grid intensification is essentially a metric process, and it occurs are the local urban scale at which people are able to make reasonable judgements of distances. But as we have seen, at the larger scale, it is the geometric and topological properties of the grid which regulate movement, and we see in the case of Santiago that grid intensification only occurs within the envelope define by the large scale north south connections over the river and by the dominant westward connections defined by the grid. This illustrate the fact that the *polycentric process* is driven by both local and global factors.

We can illustrate some of these global factors by looking at the patterns forms by our choice measure, applied with *least angle* rather than metric distance, since it is a more global measure. Choice, it will be recalled, measures the degree to which each line segment lies on paths between all pairs of line segments in the system, and so measure the *through-movement* potential, in contrast to the *to-movement* potential measure by the integration (or closeness) measure. Unlike the patterns formed by the integration measure, which often approximate the deformed wheel, the choice measure tends to define a *network*. We can see this clearly in the four cities of *Figure 16,* re-analysed for global choice:

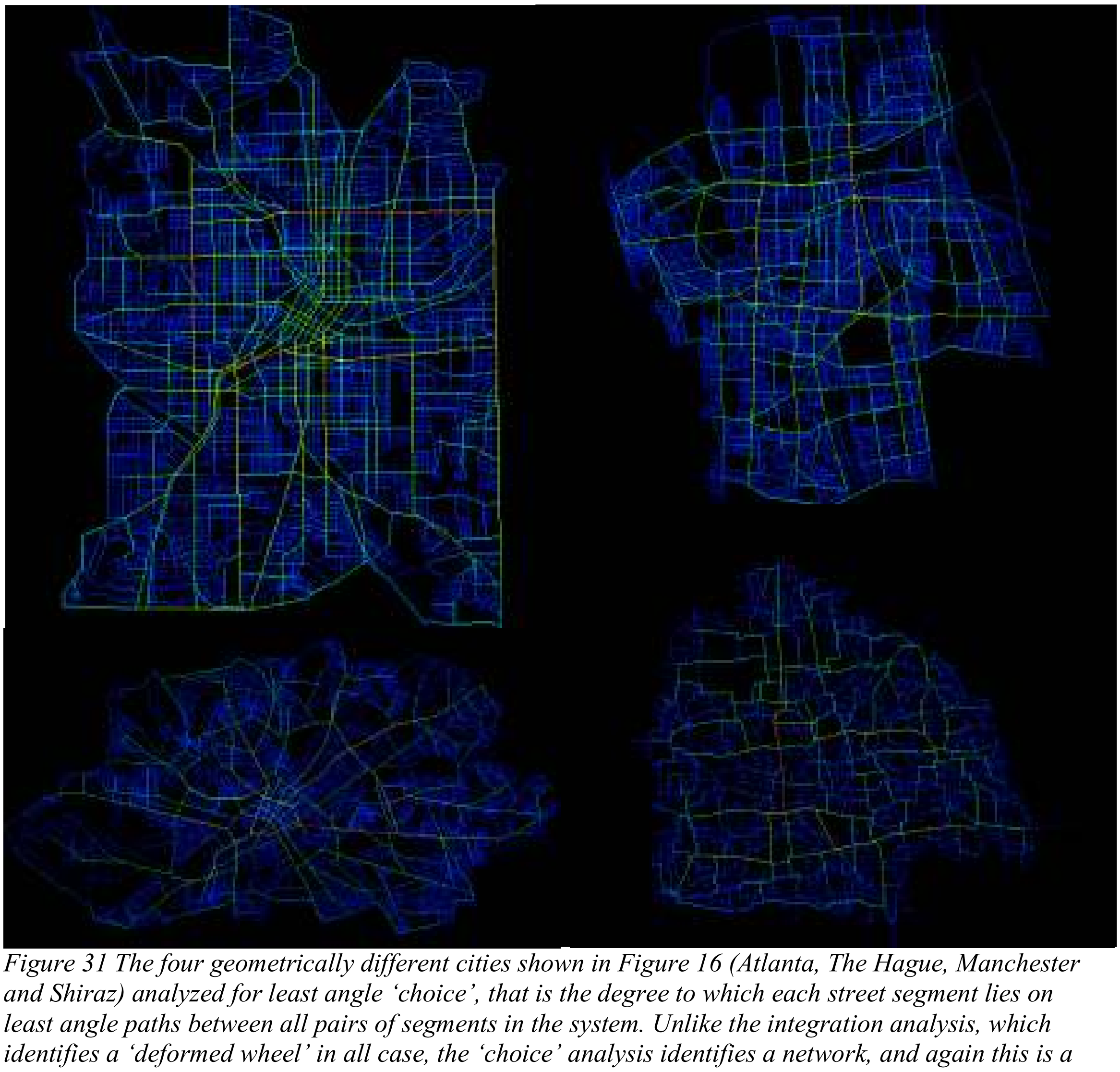


Figure 31 The four geometrically different cities shown in Figure 16 (Atlanta, The Hague, Manchester and Shiraz) analyzed for least angle 'choice', that is the degree to which each street segment lies on least angle paths between all pairs of segments in the system. Unlike the integration analysis, which identifies a 'deformed wheel' in all case, the 'choice' analysis identifies a network, and again this is a common structure in spite of geometrical differences.

Again, we find a common structure, in spite of the great geometric differences in the spatial fabric of the cities.

We also find that the *scaling* of the network varies with the *radius* at which the choice measure is applied. This can be clearly seen in *Figure 32* in which the choice radius is progressively decreased from about four miles to 400 metres:

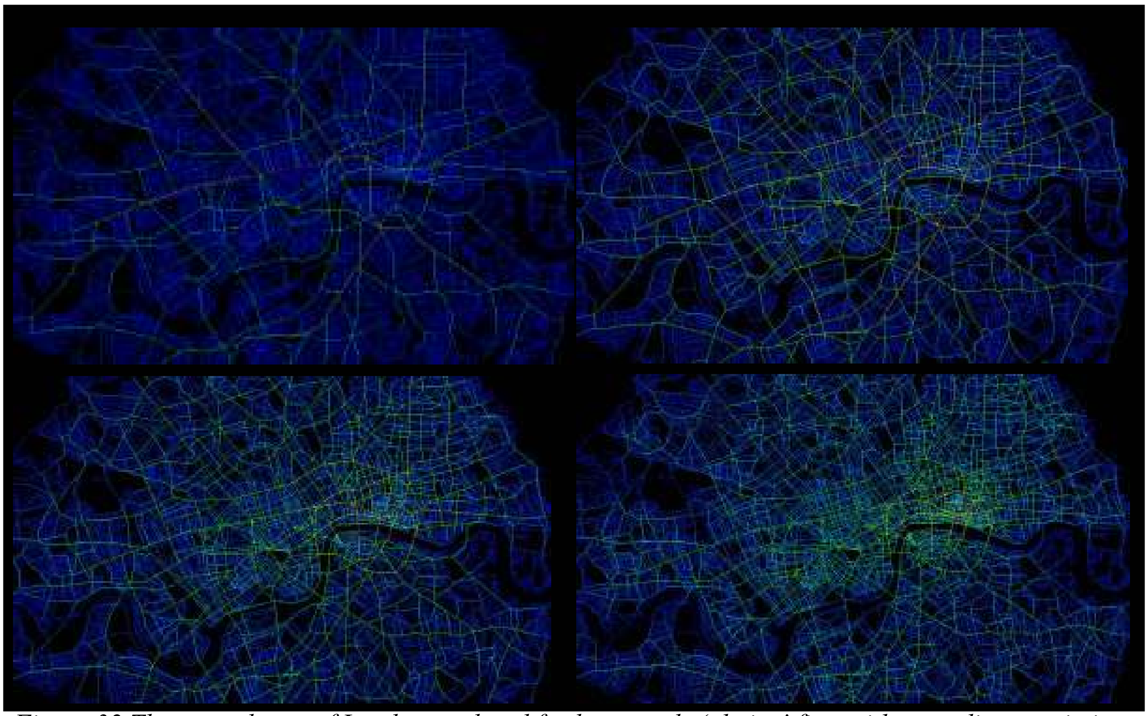


Figure 32 The central part of London analyzed for least angle 'choice' first without radius restriction, then at decreasing radius. As radius decreases, the analysis picks out a finer and finer scale network, reflecting the kinds of route choices that are likely to be made as trips decreases in length.

Key line segments with centres on them move in and out of the picture as the radius scale is changed, so that lines why are important globally are quite unimportant locally, and vice versa. Current research is examining how far the scaling of centres responds to scale variations in radius both for the integration and choice measures. But it is already clear that the relation is powerful and systematic.

This then is how cities become polycentric in the strong sense. The process works both with the local properties of space, where metric factors are the critical ones, and global factors, where the geometric and topological properties of the grid are critical. The best urban places resolve both at once, and we find thhis in cities all over the world – even in the much maligned cities of the US. For example, in Atlanta, often taking to be one of the least urban of cities, we find marvelous little local centres like Virginia Highland (named after the intersection of main roads), whose historical evolution over two centuries can be seen in *Figure 33:*

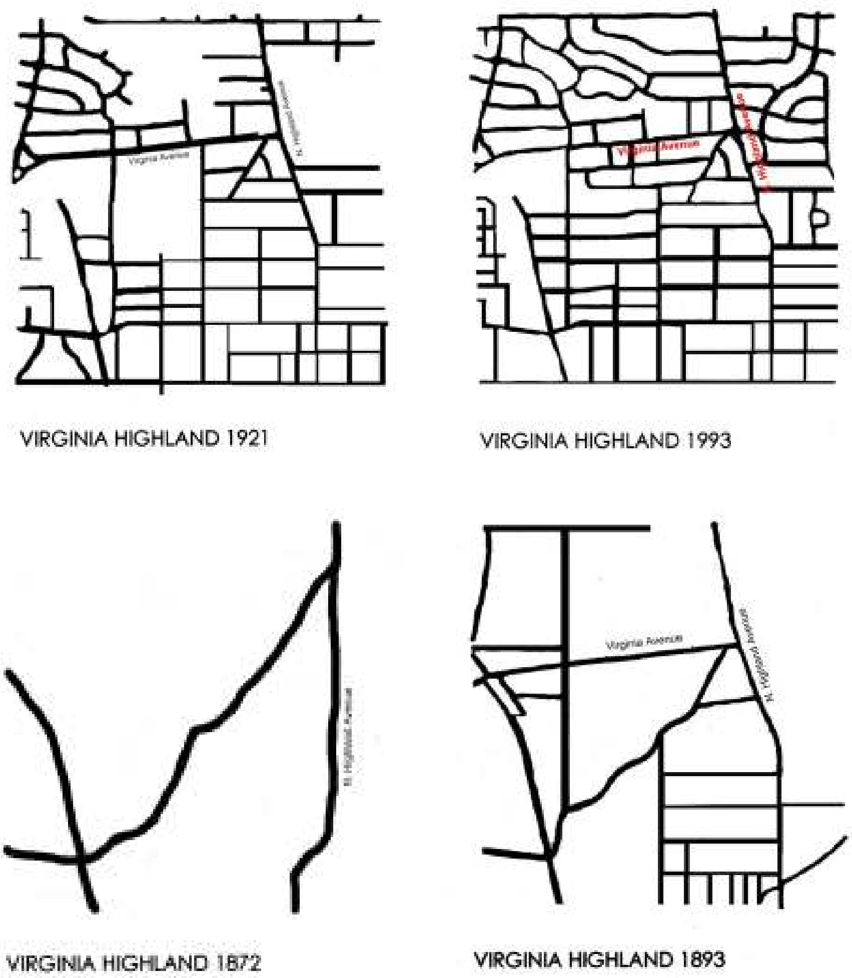


Figure 33 The historical evolution of a local centre, Virginia Highland in a US city, Atlanta, from 1872 to 1993, showing how global (the intersection of two main boulevards, Virginia and Highland) and local (the grid intensification around the intersection) factors combine to form the centre.

Showing clearly how the centre arises from a combination of local metric process of grid intensification and the global topo-geometric process defining the larger scale urban structure.

Thinking as designers

This model of how cities develop has some implications for how we should think as designers.

First, the urban grid should not be seen an inert background to human activity, but a *historical record* of a city creating process driven by human activity.

Second, space can be used *generatively* to create life in cities, and *conservatively* to support cultures by engineering space to create *co-presence through movement* to varying degrees. How cities balance these is on of the prime sources of the *individuality* of cities.

This reflects the fact that the process that creates the city is a *dual* process: a *public space* process which is driven largely by *micro-economic* factors which are *invariant* and tend to give cities *similar global structure*; and a background *residential space* process, which is driven by *cultural* factors and thus tend to make cities *different* from each other. But both reflect the laws by which the grid shapes movement, but used differently. In *public* space we *maximise* local and global *integration* to maximise *movement* and *co-presence*. In *residential* space, depending on culture, we restrict and modulate movement and co-presence to some degree to support the residential culture - while still retaining enough to make it human and safe. We should not mistake one for the other.

Third, the relation between *activity* and *space* is not direct, but generic. It *passes through* the demands that different activities make on *movement* and *co-presence.* Urban space does not then reflect the relation between this activity and that activity, but the *generic* relations between *kinds* of activity. Because as society evolves there is always a range of activity from those that need co-presence through to those that do not, this is why *new patterns* of *activity* fit so naturally into *old patterns* of *space*. Thus in the city of London the place of activities which were concerned with linking making, distributing and transacting has been taken by activities concerned with recreation and leisure, and the street based spatial culture of the city maintains itself in a new form.

Finally, everything that happens in the city has a *global* as well as a *local* dimension. In designing places, the success of our efforts with often depend on get the global relations right as well as the local ones. Most of the projects space syntax is involved in are in some sense about integrating the urban fabric and new place in it.

Broader theoretical implications

The results that come from looking at buildings and cities in a syntactic way also have broader implications for some of the generic unsolved questions in architectural and urban theory: the *form-function* question, the *self-organisation* question, and the *art-science* question.

On the first, space syntax shows that in buildings and cities alike, the relation between form and function passes through space, and more precisely, through the patterning or *configuration* of space. By clarifying the intermediary role that spatial configuration plays between physical form and the human activity, space syntax opens the way to a design level theory, non-deterministic but rigorous, of how buildings and places respond to, and shape, human activity, that is, how function shapes form and form shapes function. (Hillier 1996)

The second follows. By clarifying the link between human activity and space, we begin to understand the role that *self-organisation* plays in buildings and cities. This is particularly critical to our understanding of cities, where the great puzzle is to understand how in spite of being, for the most part, created ‘bottom-up’ over centuries by innumerable hands, cities somehow emerge as well ordered systems with an apparent life of their own. By clarifying self-organisation, space syntax shows the path to a new approach to city design, one which works *with* the natural self-organisation of cities rather than against it. It also shows a new potential for the modelling of cities. Traditional models have always use simplified assumptions about human cognition and behaviour in constructing models of cities, and as a result have not understood the agency that the geometry and topology of space has in creating urban dynamics. As a result, such models have been as far removed from the experience of living in the city as they have been from practical design. Space syntax shows by building scientifically testable phenomenological dimensions into models, and focussing thath models on the 'real space' structures of the city, that bridges can be built between humanities based and science based approaches to the city, a synthesis which many would think is long overdue.

Finally, by clarifying space at the level of precision we require in design, we show that architecture and urbanism are sciences as well as arts. Through the science we study all kinds of architectural and urban *phenomena*, and then use the theoretical understanding this yields to inform design. In this way, we build a science which is not intended to tell designers what to do, but to help them better understand what they are doing, and what they might do. In its design phase, architecture is an art, but by developing its scientific counterpart, that is, a science of the forms that have been and can be created by architecture, it confirms that architecture is an analytic and reflective science, as well as a creative art.

End

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