THE FOURTH SUSTAINABILITY, CREATIVITY: statistical associations and credible mechanisms

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ABSTRACT

In this paper, it is argued that over and above the three city sustainabilities of energy, society and economics, there is a fourth: creativity. It poses the question: can credible mechanisms be identified through which cities are more creative than other forms of settlement, as statistical evidence suggests ? It proposes that just as mechanisms can be identified linking the generic form of cities to 'spatial sustainability' for the first three, mechanisms can also be identified for creativity through the ways cities generates social networks. But whereas the first three sustainabilities are consequences of the form of the city, the fourth sustainability, creativity, is argued to be the reason for the form.

Creativity: the fourth sustainability

Cities have been getting a good press in recent years. This is quite a turn round, since for a century and a half it has been widely believed (with exceptions that are too familiar to mention) that large dense aggregations of people were so unlike the ways in which societies had previously been organised in space, that they were likely to be in themselves socially negative. While this view prevailed, there was little concern as to what we might be losing if new communications technologies made cities unnecessary. Now cities are more and more seen as positive, not only because they are seen as sustainable in many senses, but also because the very factors of scale and density which had been associated with social disorder and malaise, are now seen also as key factors in the intellectual creativity through which cities become drivers of economic and social development (for example, Bettencourt and West 2010, but more recently McKinsey Global Institute 2012, Florida 2012.

If cities are somehow in this sense creative, then this must surely become, over and above the environmental, the economic and the social, the fourth sustainability. But what is it about cities that 'creates creativity' ? We are familiar with arguments about how companies benefit from spatial aggregation, but there is little to suggest theoretically why spatial aggregation in cities, rather

than, say, out of town business parks, should lead to more creativity. Space syntax doesn't seem to help with this question. It tells us something about how cities work, but not whether or why we need them. It is not clear if space syntax could ever help. If cities do somehow 'create creativity', then it must surely be by influencing social networks, and these seem largely driven by non-spatial factors which do not seem to map significantly onto the micro-to-macro scale analysis we associate with space syntax.

In this paper, it will be suggested that the situation is not so negative ! At least a theoretical argument can be put together which links different kinds of emerging evidence into a coherent spatial picture of why and how cities might be more creative than other ways of spatially distributing the same number of people. The paper will first sketch the space syntax view of the city as space, and review the system of credible mechanisms through which, it argues, cities go from being collections of buildings to living social, economic and cultural systems with a generic underlying form (set out more fully in Hillier 2012a, 2012b). This system reflects the interaction of micro-economic and social factors, set against the background of minimising distances, and so in this sense, expresses the interaction of the three main factors in sustainability, suggesting that evolved cities manifest a 'spatial sustainability' from which it was argued in (Hillier 2009) we have much to learn. It will then address the fourth sustainability: creativity, and pose the central question: there is a statistical association between cities and creativity, but are there credible mechanisms linking one to the other ? It will be argued that the generic form of the city that gives rise to 'spatial sustainability', also relates closely to credible mechanisms through which different kinds of social networks are generated in cities, and this suggests ways in which the spatial form and functioning of cities could be related to creativity.

Syntactic structures in cities

First, let us look at the structural picture of the city brought to light by space syntax analysis of street networks, and how this generates the 'living city'. The basic unit of analysis in the syntactic analysis of cities, is the street segment between junctions. We calculate the potential of each for to-movement from all others by mathematical closeness (or *to-movement* potential), and for through-movement between all others, by mathematical betweenness (or *through-movement* potential), and we do so under three definition of distance – shortest paths (metric), fewest turns (topological) and least angle change (geometric), and under varying metric radii from each segment – so a typical

measure would be *least angle betweenness at a radius of 2 kilometers.* Comparing theoretical to and through movement at different radii with real observed movement show that both predict movement, usually with an r-square between .5 and .8, though which measure is best varies with morphological circumstances. Prediction is generally best with the least angle definition of distance, and least good with the metric definition. Different scales of movement also correlate best with different radii of the measures, with a radius of about 400 metres for pedestrian movement in areas like market places, 800-1200 metres for normal urban pedestrian movement, 3-5 kilometres for cycling, and without radius restriction for vehicular traffic. The best measure across all scales is usually one that combines closeness and betweenness, and called *normalised choice* (Hillier 2012b), which also allows numerical comparisons between systems of different sizes.

The relation between the urban grid and movement is the generator of the process by which the different parts of the city acquire differences in the form and level of activity. Locations which the grid has made movement-rich attract land uses which need movement, which in turn generates more movement, setting in train the process through which cities acquire their generic dual form of a foreground network of linked centres at all scales, set into a background network of largely residential spaces. Figure 1 The foreground network is driven by micro-economic activity, and so concentrates movement, and can be seen as morphogenetic since its aim is to bring people together and develop, the background network by socio-cultural factors, and diffuses movement, and can be seen as conservative, since it aims to structure movement and reproduce existing social patterns. The foreground grid also generates the links between a city and its neighbours in the local system of cities, and the background grid will normally depend on these connections rather than having its own.

Pervasive centrality

Space syntax purports to be, in effect, a testable (and constantly tested through applications!) structure-function theory of the city, relating the geometry, topology and metric scale of space to multi-scale movement, land use patterns and densities. A key outcome of the process it describes is a pattern of centres we call *pervasive centrality*, by which we mean that centrality functions such as retail pervade the urban grid at all scales, creating a far richer and complex pattern of centralities even than envisaged in concepts of polycentrality. It comes into existence through something like the following process (again this is set out more fully in Hillier 2009). Every centre has a centre. It starts with a

spatial seed, usually an intersection, but it can be a segment. The seed of a centre will have to- and through-movement potentials at a range of radii, but at least covering both local and non-local levels. The spatial values of the seed for the centre will establish what we can call a fading distance from the seed which defines the distance from the seed up to which activities like shops will be viable. This is a function of metric distance from the seed proportionate to the strength of the seed. The centre will grow beyond the fading distance established by the initial seed to the degree that further seeds appear within the fading distance, which reinforce the original seed. Again these can be local or global, and stronger or weaker. A centre becomes larger to the degree that it is reinforced by what are, in effect, by new seeds created by the grid which allow the shopping to be continuous.

Centres then expand in two ways: linearly and convexly. Linear expansion, the most common case, will be along a single alignment or two intersecting alignments, and occurs when the reinforcers are more or less orthogonal or up to 45 degrees to the original alignment or alignments. Oxford Street in London, for example, is a strongly linear east-west centre, shaped by the series of powerful north-south alignments which intersect it, for the most part at 90 degrees. Convex expansion will be when the shopping streets form a localised grid, and this occur when reinforcers occur on the parallel as well as the orthogonal alignment. So centres vary in the strength of their local and global properties and reinforcers, and the balance between them will tend to define the nature of the centre. Most centres will be in some sense strong in both in local and global terms, but differences in the balance between local and global will be influential in generating the scale and character of the centre. Centres also grow or fail, of course, through interaction with neighbouring centres at different scales, and some potential locations for centre fail to be realised due to the existence of centre close by, but the way in which the urban grid evolves tends to ensure that seeds for potential centres occur only at certain distances from each other.

The centres that emerge from this process have certain critical properties. First they are *multi-scale* in the precise sense that they feature strongly on to- and through-movement at both more local and more global scales. This can often be shown simply by the differences in to- and through-movement values at different radii on the different segments that make up the key line or lines of the centre (see Hillier 2009). At the same time, most centres peak at a particular scale, though what this scale is, or the range of scales at which a centre is strong, will vary from entre to centre. Because they have these

properties, centres must be seen as linking the local to the global scale (though only some at the scale of the whole city) rather than being simply 'local centres', though of course they are that too. This is vital to our understanding of how the foreground and background networks operate in cities.

Second, the fact that centres at all scales either have, or acquire, a smaller scale 'intensified' grid (Hillier 2000) allows us to bring to light a remarkable metric dimension to cities. If instead of using least angle distance in our measures, which identifies the linear patterns that correlate with movement and land uses, as in Figure 1, we use shortest path, or metric, distance in relation to to-movement potentials, we identify not linear patterns but a two dimensional periodic patchwork, which looks like an area structure, one which varies in scale according to the metric scale of the measure. For example, Figure 2a is the periodic patchwork identified by calculating mean metric depth from the centre of each street segment to all others within 500 metres for Istanbul. This can be represented in a 'mountain scattergram' Figure 2b in which the x-axis is metric integration at the scale of the whole city (and so runs from the geometric centre of the city on the left to the periphery on the right), and the y-axis is local metric integration at a scale of 500 metres. The peaks of the 'mountains' are the local centres of areas, at different scales according to the size of the mountain. If we increase the radius, the mountains become less peaky, but remain mountains corresponding to the areas defined at that radius. In most cities, it is this multi-scale *periodic structure* that seems to define the – equally multi-scale – sense of urban areas, rather than clear physical or spatial boundaries, and it is this kind of structure which often allow cities to combine *spatial continuity* with area differences (Hillier 2010).

Spatial sustainability

These mathematically defined, but functionally potent patterns show us that the city is not a collection of well-defined cellular areas linked by a superordinate master network, but a much more complex spatial network in which the relations between scales is primary at all levels. More critically, the different patterns of land of uses associated with the two components of the dual grid, show that the foreground network drives micro-economic activity by focusing movement while the background reflects social and cultural restrictions by diffusing it. More simply, the dual grid reflects the fundamental distinction between work and residence that shapes all urban lives. This is perhaps why it is the dual grid that seems to define the city, and perhaps has always done so. In view of the near universality of this form, it could perhaps be

conjectured that it was the discovery of this efficient way of linking of the economic and social functions that made the city possible in the first place. As we have already noted, from the point of view of sustainability, the generic form of the city seems to be the product of interaction between micro-economic factors structuring the foreground grid, and socio-cultural factors structuring the background grid, against a general background of optimising accessibility of all parts to all others, so the generic city that has evolved could be expected to exhibit what we might call *spatial sustainability* (Hillier 2009).

The fourth sustainability

But what about the fourth sustainability: creativity ? The starting point, as suggested earlier, is that if there is a mechanism through which cities become more innovative than other forms of spatial existence, then it is likely to involve social networks. If this mechanism involves space, then it would suggest some relation between social and spatial networks. This seems unpromising. Social networks seem only trivially to interact with spatial networks at the syntactic level of the street system. Most relations outside families are based on 'interest groups', which are by definition non-spatial. So if it is a truism to say that cities exists to create contact between people, what kind of contact can this mean ? It can hardly be just meeting in the street. That would involves too few people, as streets, however busy, are largely anonymous. But in another sense there are far too many people in the city – you cannot possibly contact them all, or even a good proportion of them. So what does it mean to say cities are about contact ? You're thought mad if you talk to people in the street, and the more the madder In what follows, it will be argued that cities do create social networks, but of two very specific kinds, and that these reflect the dual form and functioning of the urban grid as we have described it. It is in these senses, it will be argued, that cities are about making contact. These processes is so basic, it will be suggested, that if the first three sustainabilities are the consequences of the dual grid, the fourth sustainability, creativity, may be the reason it is there is the first place. This is what cities are *for*.

Recent research

First, some history. In the early stages of its development, social network analysis was preoccupied with networks than were dense – the contacts of individuals were in contact with each other- and multiplex- individuals were in contact with each other for several different reasons (playing golf, being someone's grocer or cousin, and so on). These were thought to be the

characteristics of village communities, which were taken to be in their nature superior to sparse and supposedly anonymous urban networks. Then came Granovetter, who showed that economic opportunity was related not to the 'strong ties' of the dense parts of individual's network, but to the 'weak ties' in its sparser and more diffused parts (Granovetter 1982).

Other work found strikingly comparable results. Particularly interesting from our present point of view was Allen (Allen 1977) who showed that innovation in research and development was related not to the intensity of contacts within groups, but to contacts between groups, suggesting that contacts which generated innovation were not those you collaborated with every day, nor those with nothing in common with you, but those at, in some sense, the *right conceptual distance* from you, neither too close or too far. Below I will call these '*contacts of the right kind*'. Contacts of the right kind are those more likely to make links between ideas and generate new ones. Are there ways in which cities can produce contacts of the right kind, more than other spatial arrangements ?

We can begin by noting that the idea that dense local networks are socially and economically limiting, and benefits tend to come from more diffused networks, has received remarkable scientific confirmation in a recent paper by Eagle et al (2010) on communication patterns and economic development. In a study of mobile phone calls in England, forming a graph with 102m nodes and 368m links, it was shown that those living in socio-economically successful areas had networks that were both socially and spatially more diverse, while those in less advantaged areas had networks that were more concentrated socially and spatially. Under-privileged areas did not have lower volumes of calls, but they were more localised and more focused on particular individuals. At the same time, they were denser, with social advantage clearly associated with non-dense (I will call them 'hybrid' below) networks, a finding emulating earlier work by Burt showing that remuneration in an organisation was positively correlated with the number of 'structural holes' (meaning the lack of density) in an individual's network (Burt 1992) . It was also found that as the number of an individual's contacts increased, the amount of contact per contact decreased, suggesting again that it is not simply the quantity of contact that matters, but its type.

These results seem to generate an even more serious problem for the idea that cities generate creative networks. If cities do in themselves somehow generate social networks, common-sense suggests we would expect them to be primarily local and dense, reflecting the local scale and spatial closeness of populations.

But such networks are associated with social disadvantage. So the questions become: how can the city create spatially dispersed non-dense networks, and why should they do so ?

Seeing networks spatially

As a first step towards addressing this question, it is useful to picture social networks in a spatial way, while taking care not to mistake them for literally real spatial patterns. The fundamental unit of urban spatial experience is the isovist, made up of a local convex area, where everyone can see everyone else, and the 'spikes' reaching out into non-local areas where people cannot see each other Figure 3. This has a remarkable resemblance to an individual's social network. There is a convex core where everyone knows everyone else, and 'spikes' reaching farther out into the network, where people do not directly know each other. Noting that there is no standard term for 'spikiness', as oppose to density, I will call the spikes the *hybrid* parts of the network because they originate in idiosyncratic rather than shared sources. (*Footnote: The term 'hyrbid graph' is used by Lehmann, Post and Kauffmann 2006 to mean a mixture of random and non-random elements in a graph. The term is also used in physics in relation to dynamic systems which exhibit both continuous and discrete behaviour. Neither seems a good reason to avoid this natural term to describe positively a key property in social networks).* We can also use the spatial analogy to generate a picture of the whole network. The hybrid spikes reaching out from the dense local groups can be seen as tending to form a socially and spatially more diffused *foreground* network, linking the dense, more localised *background* networks. The spatial and social systems do not of course map onto each other on a one to one basis, but the structural similarity of the two systems is striking, and, as we will see, there is a structural relation between them. At this stage, we can at least begin to think of social networks in the same kind of way we think of spatial networks.

There are some simple, but important, numbers associated with *hybrid-dense* systems. We can think of the everyday intuitable limits of an ego centred network as having 4 levels, 3 from ego, as in, for example: *I met a man whose father knew Lloyd-George*. If we allow each individual to know 9 people, and in one case 3 are dense, so already in the network, and in the other 6 are dense, then at level 3 (the Lloyd-George level) there are 388 people in the more hybrid system and 118 in the denser system. At one more step, the difference is 2331 against 360. We could note that if everyone knows 100 people, and none are dense, then there are 1 million people at the Lloyd George level, and one more

step exceeds the population of the UK, and one more of the world. Real world graphs are not of course as shallow as this – the mean distance in the Eagle study was 9.4 – but they are shallower than we think, and we should never be surprised to discover indirect connections to someone we meet. But practically speaking, for our present purposes, holding contact volume steady (as evidence suggests we may), hybrid networks should be very much bigger than dense ones. Example of Benny connections – or is this beside the point ?

Three interacting factors

We seem then to have three interacting factors. We have social networks which vary from the hybrid to the dense; space, which varies from the more integrative in the foreground network to the more segregative in the background; and social status, which varies from advantage to disadvantage. We know already that there is a relation between social networks and social advantage, in that socially advantaged networks are more hybrid, and between social networks and space in that socially advantaged networks are more spatially diffuse. Recent results show there are also relations between space and social advantage. A recent study (Hillier and Barnes 2008) covering over 100,000 dwellings in a sector of London showed that house value, as measured by 'Council Tax' (a tax based on house value) correlated linearly and positively with global integration. We also found a relation between space and social advantage at the national level (Hillier and Serra 2014). Using a syntax map of the whole of the UK, giving syntactic values to every road and street segment in the system, we found that income correlated positively with integration at a radius of 90 kilometres, showing that integration is a key property in systems of cities, as well as in individual cities. We can reasonably assume that the relation between social advantage and space is two way: we construct the relation through the way we build cities, and then space plays a role in perpetuating social advantage. Another key relation shown by the same study is that job density, but not income, correlates strongly with integration at the local radius of 2 kilometres, so, not surprisingly, the areas associated with pervasive centrality.

It is clear then that there is a relation from social networks to space, though it is not clear yet what mechanism could explain this. But there is no notion of a relation between space and social networks, as we would expect there to be if the city plays a role in creativity. The one thing we know the space structure of the city does in and of itself is create patterns of co-presence through movement. If this seems a weak outcome for the massive investment that the

city is, we have seen that it is enough to set in train, and maintain, the processes through which collections of buildings become the living economic and social systems we experience. We might then expect these massive patterns of co-presence would somehow create the kinds of social networks that advantage cities, an 'urban creativity' process of some kind. But this idea, as we have seen, leads to paradox. The network patterns associated with social advantage seem inconsistent with what we would expect the effects of the city would be. The problem then is to identify a credible mechanism through which cities can create spatially dispersed networks, and the advantages that seem to come with them ? How do cities create networks of the right kind ? To take the next steps, we need to complicate our model of what a city is as a spatial and social system, and for this we need to bring in some new theoretical concepts.

Spatial and conceptual groups

The first concept is the distinction between spatial and conceptual groups in society. Households, villages and universities are spatial groups, families, clans and academic disciplines (and 'interest groups' in general) are conceptual groups. Conceptual groups will have a spatial distribution of some kind, but they are defined in themselves without reference to space, whereas with spatial groups space is part of the definition. Now it is a mistake to think that, because they are aspatial in their definition, conceptual groups play no spatial role in society. On the contrary, in pre-urban societies, a principal function of conceptual groups such as clans is to create the non-local relations (such as marrying circles) on which the genetic viability and social interdependence of the society and its cohabiting groups depend. This is why clans are typically dispersed across spatial groups, rather than coinciding with them. From the beginning (as far as we understand it) societies are much bigger than their cohabiting groups, and these are linked in the main by the activities and structures created by conceptual groups. (Hillier and Netto 2002)
with the emphasis on located activities ('situated practices')
Modern urban societies do not have clans, of course, but they do have conceptual groups, and for the most part these are related to the division of labour first facilitated by the creation of cities. I think it is safe to call these *knowledge* groups, because what essentially distinguishes them is the specialised knowledge that allows individuals to play a particular role in a functionally differentiated society. So architects, or bankers, or taxi drivers are all conceptual groups defined by some kind of shared knowledge forming the basis of a functional role. Micro-economic activity is essentially interaction between and among members of knowledge groups, so, as with clans, the key effect of

the existence of these knowledge groups is, precisely because they are not spatial, to create relations and encounters of a non-local, as well as local, kind.

Reflecting this, social networks for most people will then be made up of two kinds of relations: one we can approximate as 'family and friends', which will be broadly associated with the background residential, and so conservative parts of the spatial network and have some degree of durable density by virtue of being spatial (Goldenbebrg and Levy 2009); and one we can call knowledge group relations, associated with the foreground micro-economic (or more simple 'work'), parts of the spatial network, which in its nature will be morphogenetic, and being non-local nature will tend to lack spatially induced density.

Social contacts and information

Second, we must distinguish social contacts from information. Every individual is the centre of what we might call a Lloyd George system made up of information up to three steps away. This will not be all information in the system, of course, just some of it. However, from an information point of view, it would mean that the information advantages of the hybrid system over the dense system will be very much greater, since it will search the system all the more quickly. We can also make the distinction between the morphogenetic and conservative aspects of social contacts precise by making an analogy between network structures and the mathematical theory of information, using the distinction proposed by Moles between semantic and aesthetic information (Moles 11958, 1968) - though of course here we will not be talking about aesthetics, but translating the analogy into social contact terms. Moles set out from Shannon's distinction between the redundancy (or structure) of a language, and the information that it can transmit. The latter can be measured in terms of the freedom to choose permitted by the redundancy, and so the degree of unexpectedness in the message. Moles sought to explain why we go to see a play or hear a symphony with which we are already familiar. Moles distinguished between the score or story, which he calls semantic information, and saw as analogous to Shannonian redundancy, since it is always the same and known in advance, and the spatio-temporal performance, which he calls aesthetic information, noting that because it is not known in advance and always varies, it can be regarded as Shannonian information. From the point of view of experience, semantic information can be completely known, and so exhausted, while aesthetic information cannot be. Hence we go.
More structure, less information, but too little structure, unintelligible
In Moles analysis, the 'semantic' information can be regarded as conceptual,

since it is embodied in the signs of the score, while the 'aesthetic' information can be regarded as 'spatial' since, like speech in contrast to language, it is created and realised in space-time. This allows us to translate the concepts for the structure and formation of social networks. The semantic information, or redundancy, is the existing structure of the network at any point in time as a conceptual structure, and the 'aesthetic' information is the originality and unexpectedness of the information (in Lloyd George terms) in space-time created by a new spatial contact. Clearly, the more the network is dense, the more the Lloyd George information will refer to the existing structure of information, and so to the redundancy of the system in Moles terms, and the more the system is hybrid, the more the Lloyd George information will be unexpected, and so constitute information in Shannonian terms. We can also link this to the distinction between spatial and conceptual groups. The pattern of conceptual identity is part of the existing network, and so can be seen as providing a semantic (in Moles terms) basis for contacts, while the spatial contact itself, and the Lloyd George potential this generates, can be seen as the informational content, which can be much richer. This can also involve others who are present at the contact, and will be experienced by ego as additional random information, especially if the system is hybrid, as can be expected. In this sense meeting people is spatially richer than the concept of the network, just as the performance is richer than the score.

Clarification needed here ?

Levy flights and Brownian motion

The third concept is the distinction between 'Brownian' and 'Levy flight' search strategies, as applied to the ways animal predators seek prey. Here what is sought is not prey, but contacts, and so information, of the 'right kind'. Brownian motion is random local motion, and operates efficiently for predators seeking prey where prey are plentiful in a locality. But where prey are sparsely dispersed, a more efficient strategy is a pattern of movement called Levy flights, made up of a mixture of localised movement coupled to periodic much longer steps. Reasons for the greater efficiency of Levy flights in sparse target situations include both a greater range of search, and a substantially reduced chance of repeating a search in the same space. The aim of introducing this concept is not to enter the debate on how far human movement in general can be regarded as Levy flight or Brownian or neither (Gonzalez M, Hidalgo A and Barabasi 2008), but to suggest some useful conceptual analogies between these concepts and the structure and functioning of the city. In terms of functioning, contacts of the right kind are likely to be sparse and we don't know where they are, so only an efficient probabilistic search strategy is likely to bring them into

contact. More strikingly, in terms of structure, the spatial configuration of the city as we have described it in terms of foreground and background networks, seems to reflect the distinction between Brownian and Levy flight motion to a remarkable degree. The foreground network, with its strong linear relations between local centres, and the highly explorable small scale local grids of those centres, reflects the two components of the Levy flight, while the background network, with its more localised and uniform grid structure, seems more simply Brownian.

City space and social networks

We can bring these concepts together to conjecture a general theoretical model of the ways in which cities generate social networks, including a plausible mechanism for how contacts of the right kind are generated. The fundamental idea is that the city creates two different types of network, and these reflect both the dual spatial structure of the city, with its integrated foreground and localised background networks, and the dual social network with its hybrid 'integrated' foreground and dense localised background. The model is summarised in Figure 4.

SOCIAL AND SPATIAL NETWORKS: model

form → / function ↓	social network	information	groups	space	process	spatial network
stability	dense, (comm-unity)	redundancy	spatial	local	brownian	background, residence
morphogenesis	hybrid, (indivi-dual)	unexpected	knowledge	non-local	levy flight	foreground, micro-economic

The critical step is to distinguish between the two functions of social networks: social stability and morphogenesis, and link them to the spatial and social networks. Social stability in a network will be enhanced by density, in the sense that the Lloyd George information activated by spatial contact will refer to the existing structure of the system, and so constitute redundancy, rather than unexpected 'information' in the Shannonian sense. This then fits naturally into the localised background grid where space supports density. This does not of

course mean that everyone locally in the background network knows everyone else, just that a certain proportion of the networks of individuals in the area are likely to be local and dense. Dense groups are in this sense spatial groups, and as such can be generated and maintained by Brownian motion in the background network with its localised structure and lack of local to global spatial connections.

In contrast, spatial contact in the hybrid network will tend towards morphogenesis, since the Lloyd George information will tend to constitute Shannonian information rather than redundancy, due to the hybridity of the network. This then fits naturally into the foreground network where contacts are generated non-locally by interaction among and within aspatial knowledge groups, creating a pattern which resembles Levy flights in the foreground network, with its strong local to global connections, linked to the intense local structures formed by centres. We should note that it is not being argued that human movement takes the form of Levy flights, simply that the pattern of movement in the spatial network created by the contacts among and within aspatial knowledge groups will take a form, and have an effect, comparable to Levy flights in that it will be made up of non-local jumps as well as local contacts in those locations, and so will act as though it were an efficient search technique for an unknown objective. In general then, contacts in the background network will tend to reproduce existing relations, and so tend to the social stability which the spatial form and its residential function already suggests, while those in the foreground network will tend to generate new relations and so morphogenesis, again which its spatial form and its micro-economic function also already suggest.

Within this process, we can begin to see how the discovery of contacts 'of the right kind' will be facilitated. The simple fact that non-local, work-related contacts are made between and within knowledge groups sharing some common problem definition, means that there is a good probability that many will be at about the 'right distance'. Also the fact that the potential population addressed by this process will only be a small fraction of the total urban population (though substantially more than the people of the right kind that you might bump into on the street -though this need not be excluded) makes the search numerically both worth-while and viable. Most important perhaps is the scale and concentration of micro-economic activity, since this will define the scale and accessibility of the field accessible to easy direct contact. This seems likely to be related both to Florida's finding (Florida 2012) that the spatial density and concentration of centres, is a strong factor in economic success,

and also the finding in (Hillier and Serra 2014) that the level of economic activity as measured by job density is strongly related to local spatial integration.

These properties form a context for a contact process in the foreground network in which the hybridity of the system, linked to the quasi-levy flight structure of search, mean that the unexpected information generated by spatial contacts will be maximised. To this can be added the likelihood that contacts are likely to also generate random add-ons in the form of others who are also present at the contact, and these are also a likely to take the form of unexpected information through hybridity rather than known information through density. So the structure of the system of contacts generated by knowledge networks will increase the probability of finding contacts of the right kind whose whereabouts are unknown, and the bigger and denser the city, the richer and more numerous will be both the contacts of the right kind and those seeking for them. So, given an efficient search process through contacts, the bigger the system the more successful it should be in generating networks of the right kind, not necessarily with respect to particular individuals, but probabilistically, with respect to the working population as a whole. The morphogenetic pattern of contact which bring this about is fundamentally driven by the spatialisation of the aspatial knowledge groupings, not by local dense spatial groupings. This is why economic success is associated with non-local rather than local measures. It reflects how cities work economically to develop and innovate, rather than how they work to create social stability.

Summary and conclusions

To summarise, then, in the background network, social contacts will tend to be dense, reproduce existing information, and affirm spatial groupings which maintain contact locally by Brownian movement. In the foreground network, social contacts will be hybrid, generate new information, affirm aspatial knowledge groupings, and maintain contact non-locally by movement which emulates the Levy flight pattern. The larger and denser (in the spatial sense) the system becomes, and the more interactive it is, the more likely it is that links 'of the right kind' will be there to be discovered. We see then that there is a relation between the spatial and social foreground networks, as there is between the social and spatial background networks. Taken as a whole, the spatial nature of the city supports the development of both social stability and morphogenesis through social networks, and morphogenesis will lead, on a probabilistic basis, to contacts of the right kind.

It can be argued, then, that one of the fundamental effects of the city is to create non-local connections, and so to overcome distance. In this sense it can be compared to pre-urban societies where the form and nature of society is given by the devices through which society overcomes space to inter-relate a region of separate spatial groups. The difference is that whereas in pre-urban societies the space of a sparse population was overcome through the structure of social reproduction (devices like clans and age sets), in cities the space of a highly aggregated population is overcome through the structure of production. This is perhaps the basic difference between cities and other forms of human spatial organisation. In this context, it is striking, perhaps, that denseness gives a network meaning to the concept of community through the interrelatedness of a group of people, while hybridity gives a network meaning to individuality, in that an individual's network it likely to be unique, and held together only by that individual.

This is only a theoretical model, of course, but it is consistent with the many kinds of data we do have. It suggests at least that there is a remarkable analogy between the generation and functioning of social networks and the dual spatial structure of the city. We might ask then, what causes what? While in the case of the credible mechanisms through which cities go from being collections of buildings to economic and social systems, a causal role can be assigned to space through its effect on movement, in the case of the formation of social networks this seems not to be the case. We do not have a credible mechanism through which spatial structure can 'cause' social networks. Networks are created by economic and social activity, but take a structural form which reflects the spatial form of the city, so we find a profound relationship between the two kinds of network, but on a structural, rather than one to one, basis.

It seems much more likely, then, that the spatial structure of the city has evolved in response to the need for these networks, rather than vice versa – that the urban spatial structure has been called into existence to facilitate a close but distinct relation between social stability through residence and morphogenesis through work. After all, whatever else the city is for, it exists to create an economic system – and though the relation to residence, this becomes a populated economic system. We can say perhaps that if cities exist to create certain kinds of social network, and this is why they take the form they do, the first three sustainabilities are the consequences of the spatial form, the fourth, creativity, is the reason for it. Cities are shaped to create non-local social networks for micro-economic purposes, local networks for socio-cultural purposes. This is why economic success is associated with non-local rather than

local measures. And this may be what it means to say that cities exist to create contact.

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Figures

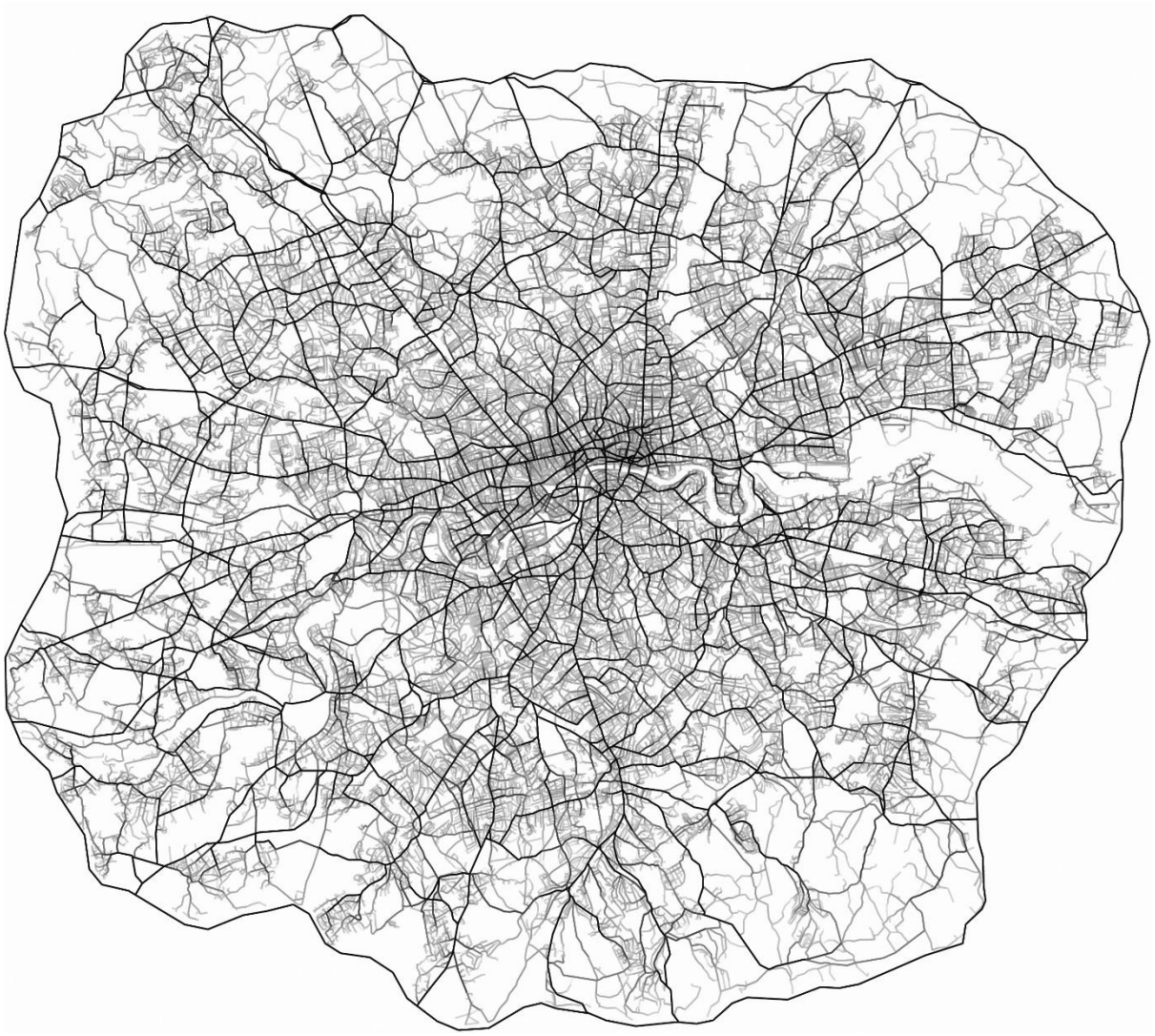

Figure 1 London within the M25: log betweenness with no radius restriction

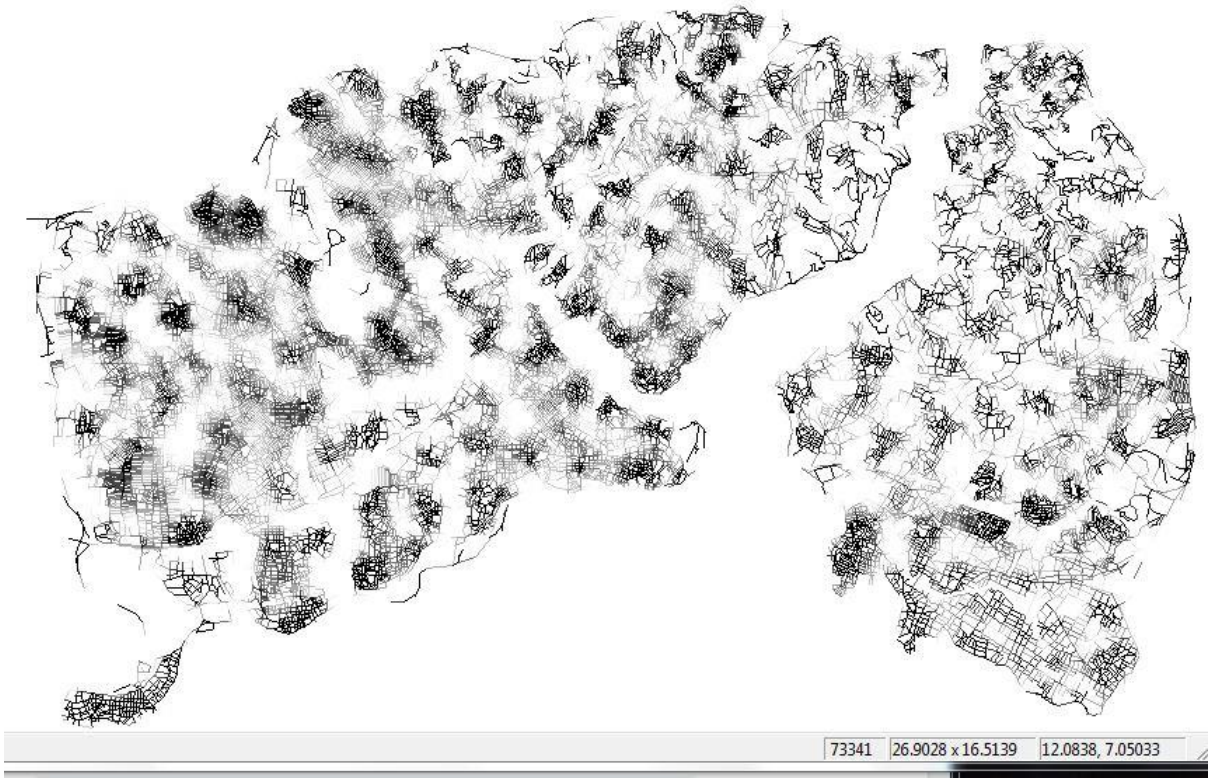

Figure 2a Istanbul: mean metric depth at a radius of 500 metres

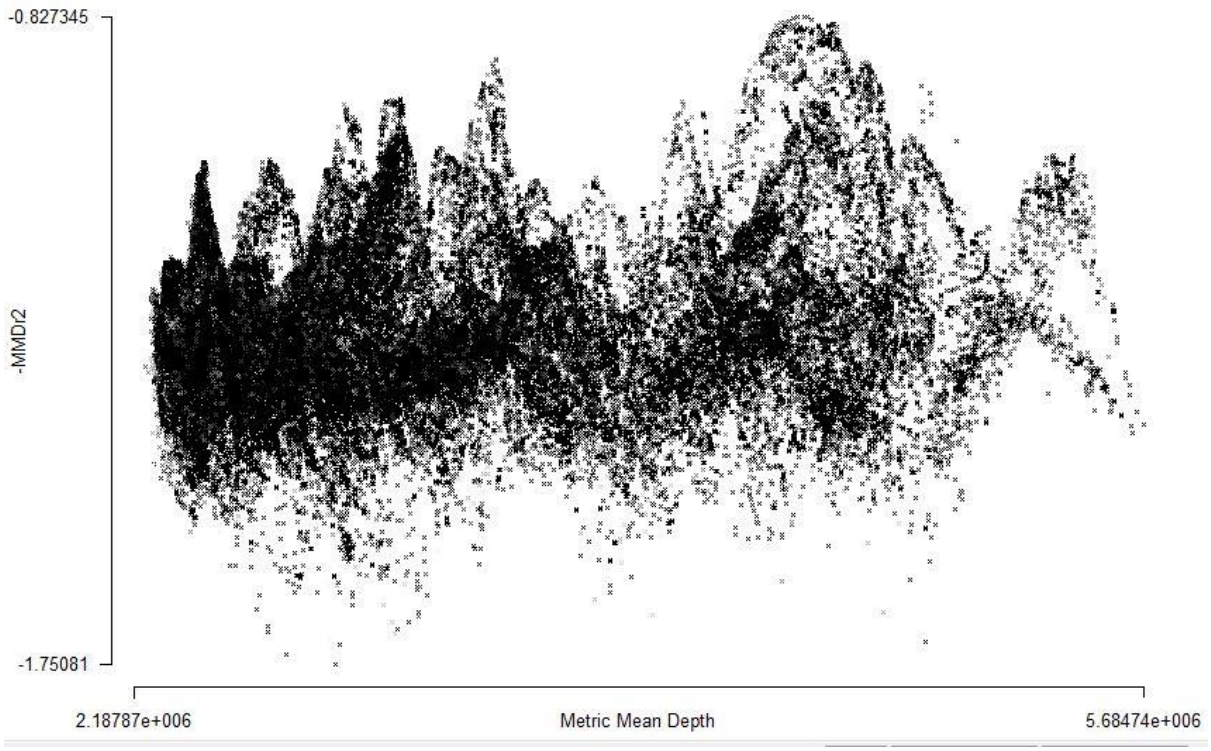

Figure 2b Istanbul: 'mountain scattergram' with mean metric depth without radius restriction on the x-axis (so centre to edge) and mean metric depth at 500 metres on the y-axis. The tops of the 'mountains' are the centres of the areas identified in Figure 2a.

Figure 3 Typical urban isovist with a convex centre and spikes

SOCIAL AND SPATIAL NETWORKS: model

form → / function ↓	social network	information	groups	space	process	spatial network
stability	dense, (comm-unity)	redundancy	spatial	local	brownian	background, residence
morphogenesis	hybrid, (indivi-dual)	unexpected	knowledge	non-local	levy flight	foreground, micro-economic

Figure 4 Model of the dimensions of variability of urban spatial and social networks