IS SPACE SYNTAX A BETTER WAY TO MODEL CITIES ?

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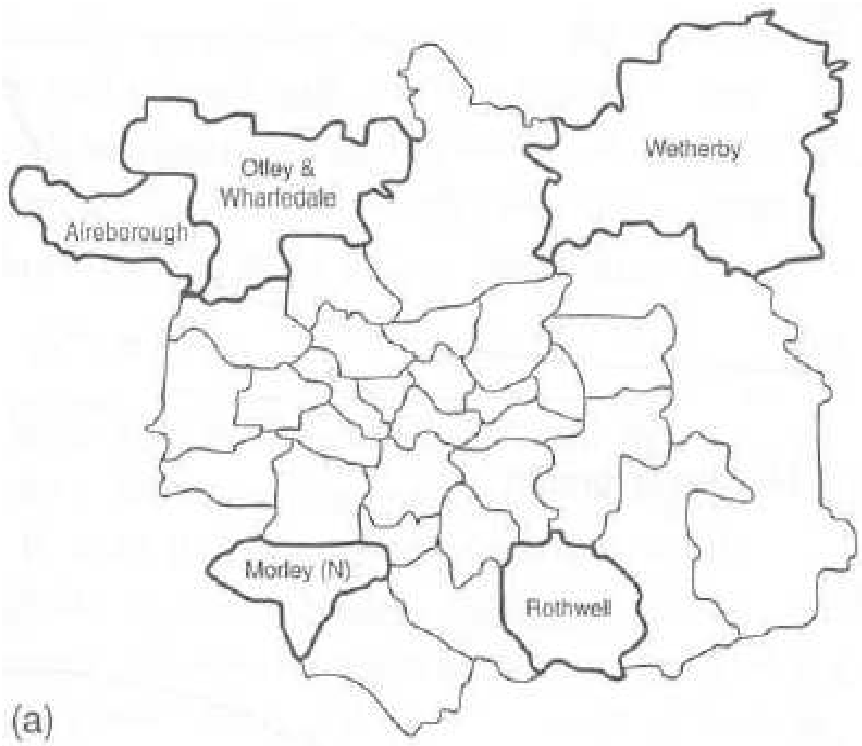
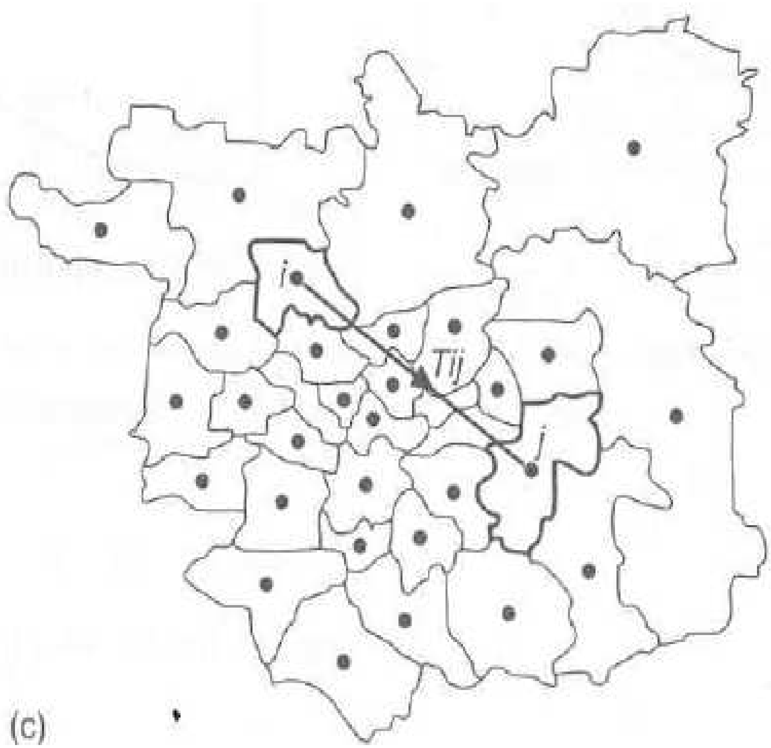
- Scientific approaches to the city have usually been through some kind of *model*. In the year 2000, Alan Wilson published *Complex Spatial Systems* in which he reviewed the history of such models. He proposed a general approach to modelling which he call the *interaction-location* paradigm, and argued that all the classical theories of quantitative geography could be re-written, and clarified, within this paradigm. The book seems to an outsider like me a major clarification of an academic tradition whose complexity has often engendered confusion.

- One great advantage of this lucid book, however, is that its very clarity enables outsiders to engage in theoretical issues within the field and perhaps to see limitations. This is my position. I have always had a distant, rather critical perhaps, view of traditional urban modelling, but saw no reasons to engage in debate with it as I was building quite different kinds of modelling approach to cities – space syntax - with quite different purposes. It was a paradigm issue. Traditional urban models were outside my paradigm, and when you are doing something new it can be a very good idea not to spend to much time engaging in arguments with other paradigms.

- But in this lecture, inspired by Wilson's lucid account, I would like to address the *theory* behind urban models – distinguishing this clearly from the practical uses to which they are put.





- My argument is this. Traditional models make a number of assumptions, inherited from different phases of their academic history:

- - that the appropriate urban element is the *discrete zone*
- - that these zones can be treated as points and assigned various kinds of *mass* – population, business density and so on
- - that the fundamental mechanism is *attraction* between zones according to their mass
- - that the fundamental dynamic is attraction-induced *inter-zonal flows* which can be assigned to the road network
- - and that the spatial field in which cities exists is a *Euclidean metric* field

- This may fairly be called a *paradigm*, and it is reasonable to say that the fundamental shape of the paradigm is Newtonian: the zones attract each other in proportion to their combined masses inverse to the distance between them. Although simple 'gravity' models are now regarded as naïve, the underlying theoretical shape of an urban model still comes from the Newtonian framework and the Newtonian equations.

- There are many familiar criticisms of such models of cities:

- - they are coarse grained and neglect micro-structure, and it is not clear how there can be a theory of macro-structure without a theory of micro-structure
- - their gross scale makes them insensitive to the level at which design and planning operates;
- - zones are arbitrary constructs and do not exist in any morphological sense
- - they are very expensive to build and very data hungry

- These are not the issues that concern me today. My problem is this. I have developed a way of modelling cities, called space syntax, which uses *none* of the conceptual apparatus of the traditional urban model, and assembles the urban bits in quite a different way. My models do not directly challenge urban models, except that both types of model claim to predict movement in some way, because the two kinds of models serve quite different purposes. We might say that mine serve the purposes of those who actually design real spaces, urban models serve the purposes of the broader policy purposes that characterise planning.

- However, at a theoretical level there is a challenge, because syntax models of cities have now produced results which suggest that urban models through their very form, may be obscuring key dimensions of the structure-function relation in cities, maybe *the* key dimensions. I speculate that this is why they have failed to develop theoretically – as opposed to methodologically - over the years, in spite of something like a century of development.

- To put it simply, our results suggest that the underlying *paradigm* of the urban model may actually be concealing the real form-function dynamics of the city. Whatever the practical usefulness of urban models, I suggest, they cannot be the basis for a *theory* of the city, whereas spaces syntax, I will suggest, *is* a theory of the city – to be precise, a theory of *urban self-organisation*: of how the complex spatial and functional patterns that characterise cities, particularly but not only *organic* cities, arise from the way they grow and work.

- So let me start at the beginning and ask what is to be theoretically understood about cities.

- Cities seem to be two things: one the one hand, a large and slowly changing collection of buildings linked by a network of space of variable geometry; and on the other a fast changing system of human activity and interaction happening *in* that space. We might call the first the *physical city* and the second the *social city*. Space seems, in some way that is as yet unclear, to be common to both.

- Urban practice must treat the city as one thing, in that is must plan and design the physical city to somehow *enable* the social city. This is the whole justification for city planning and design. Theory must do the same. It must show interdependencies between the physical city and the social city, so that in some non-trivial sense the city is shown to be *one thing*.

- So let me begin by explaining how space syntax tries to go about this. First, what exactly is space syntax ? Space syntax originated in *architecture* in the late nineteen seventies as a set of techniques of spatial description and analysis aimed at answering architect's spatial questions: *what will happen if we design it this way ? Is there another way to design this ?* To do this we had to describe and analyse spatial patterns at the level at which architectural decisions are taken. So we needed to bring a new kind of precision to the idea of spatial analysis.

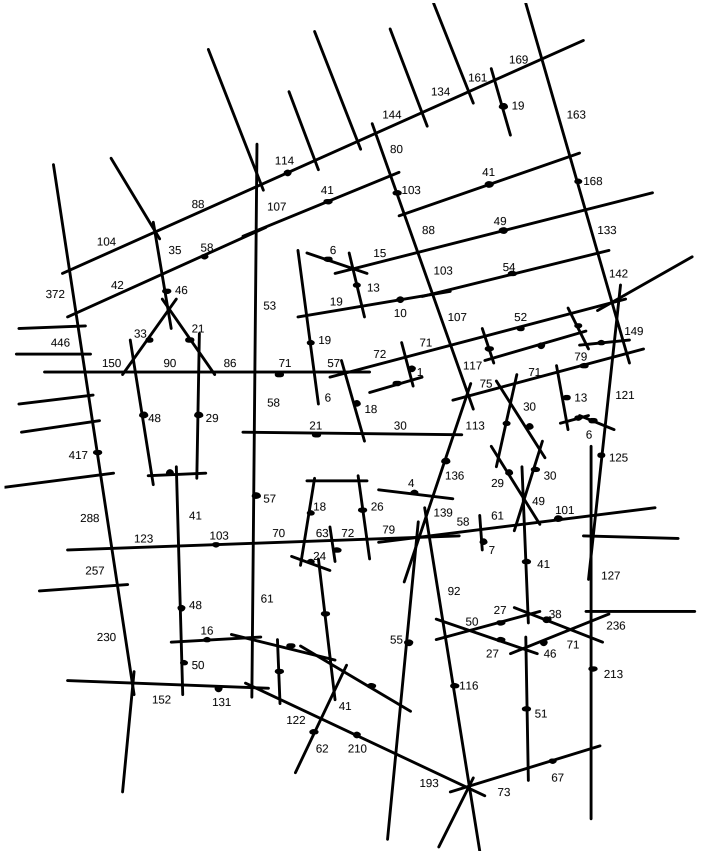
- The three key ideas in syntax are:

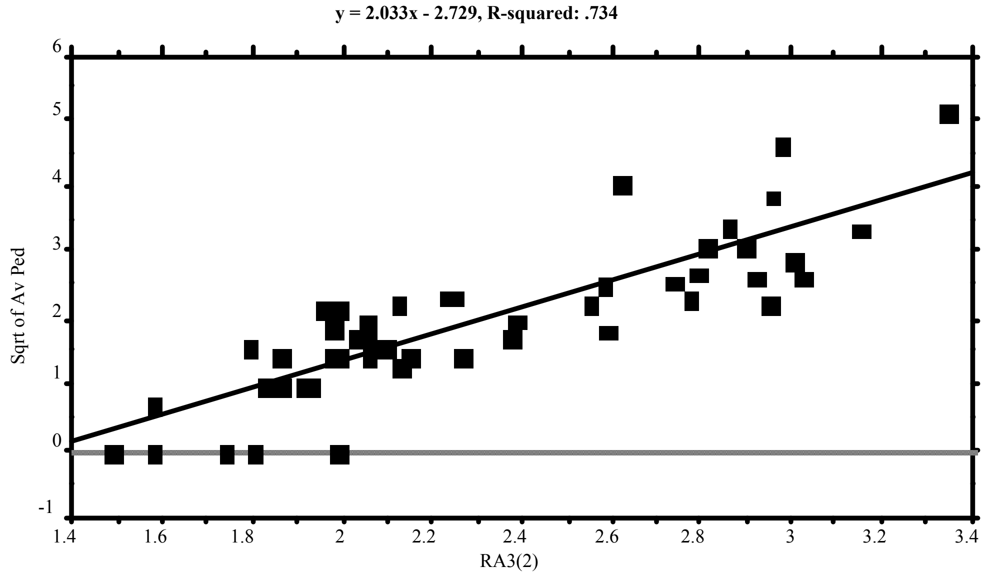
  \- spatial *representation*, but which we break a pattern of space up into discrete elements such as points, lines and convex elements;

  \- *configuration*, which we define as the relations between each spatial element and all others calculated by treating the elements as a graph,

  \- and *structure*, which we define as a the patterns formed by configurational values of different kinds assigned to spatial elements. So different configurational measures will identify different structures.

- Structures can be brought to the surface and made accessible to intuition by representing numbers as colours – usually red for some strong value through to blue for weak. Syntactic analyses aim to bring to light underlying structures in such things as settlement forms and building layouts. Above we see the structure of *spatial integration* – meaning the topological closeness of each street to all others – for an inner London residential area.

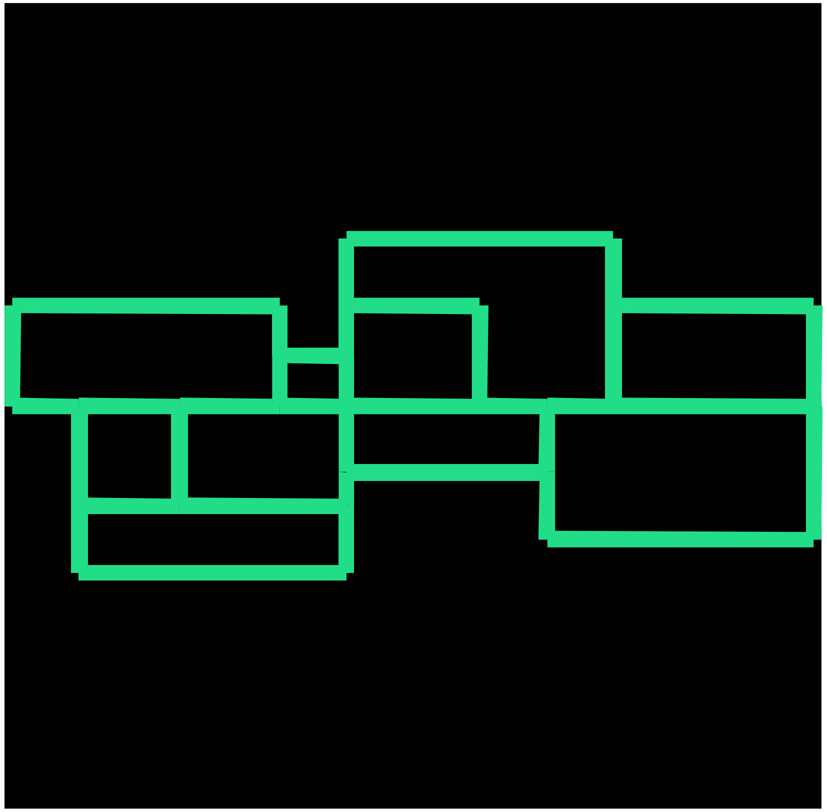
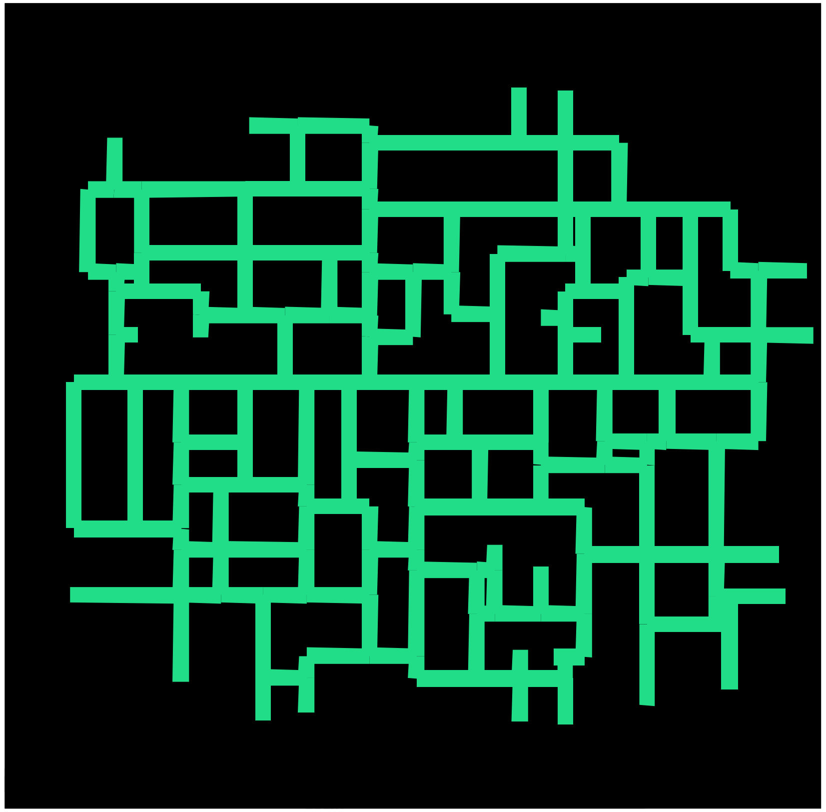




- The test of structure is function. Because space syntax is spatially precise is is possible to test syntactic descriptions of structure against function – for example, observed movement flows, land use patterns and mixes and so on - in a simple way. In the above case, we simply correlate the configurational values represented by the colours against observed movement flows. We find a correlation of around 73%, a finding which has been reproduced, through of course to differing degrees, in a very large number of studies.

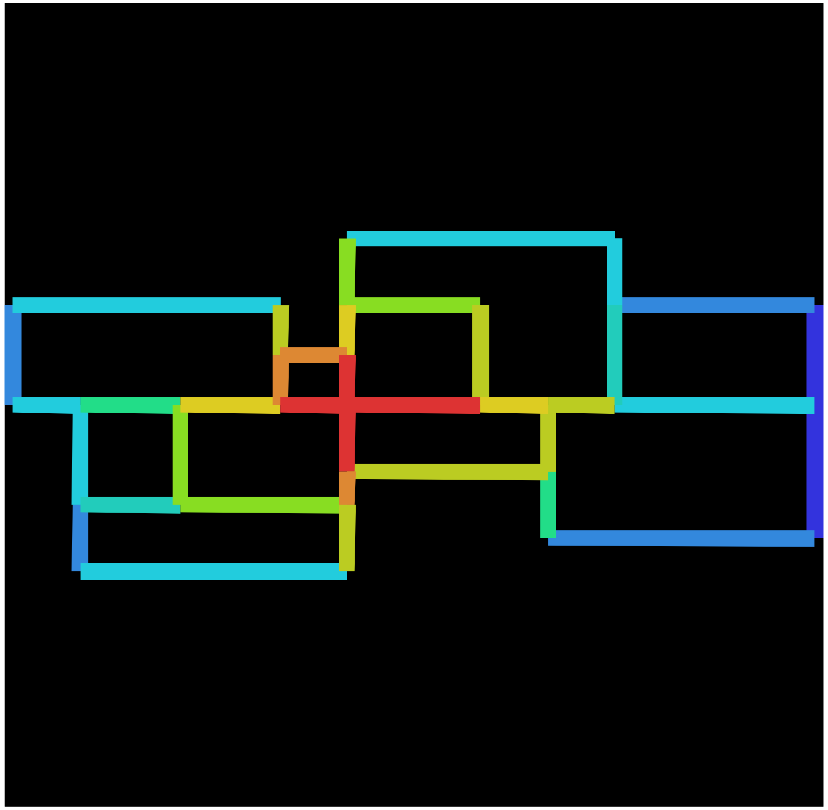
- The *fundamental proposition* of space syntax is that *spatial configuration, in and of itself, shapes movement patterns, and in doing so, shapes patterns of co-presence* within that configuration. This may be all that space does Other relations between space and function – and perhaps between space and society in general – pass through this relation. The space-movement relation should be, I believe, the *first theorem* of architecture.

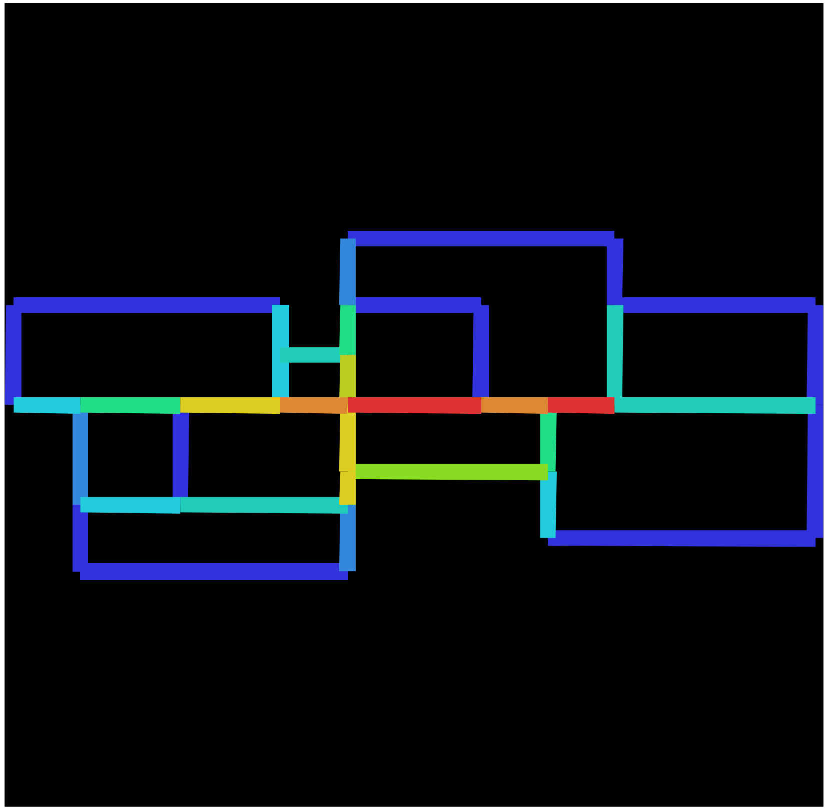
- I believe the consequences of this relation are enormous, and compel us to see cities in an entirely new way. It would not be too far fetched to say it compels us to see them in an *architectural* way.

- Although it has not been noticed before, the relation between configuration and movement is, we contend, *intuitively obvious*, *empirically the case*, *mathematically necessary*, so can be *predictively approximated* in most circumstances. Let me first try to convince you it is intuitively clear. If we imagine the notional grid left above, made up of a horizontal main street, a vertical cross street, and some side streets and back streets, to be lined with buildings, and that people move by shortest paths from each building to all others, it is intuitively clear clear that more people will pass *through* the main and cross streets than any of the side or back streets, and that more will pass through the central segments of these streets than the peripheral segments. It is also clear that some segment are more easily *accessible* than others from the system as a whole, meaning that we can more easily go *to* them. So intuitively the layout seems to affect both *to- and through-movement* potentials. If we wanted to set up a shop, we would choose a location which seemed to have both movement potentials.

- A little more reflection will suggest that this is also likely to be the case for the more complex layout on the right.



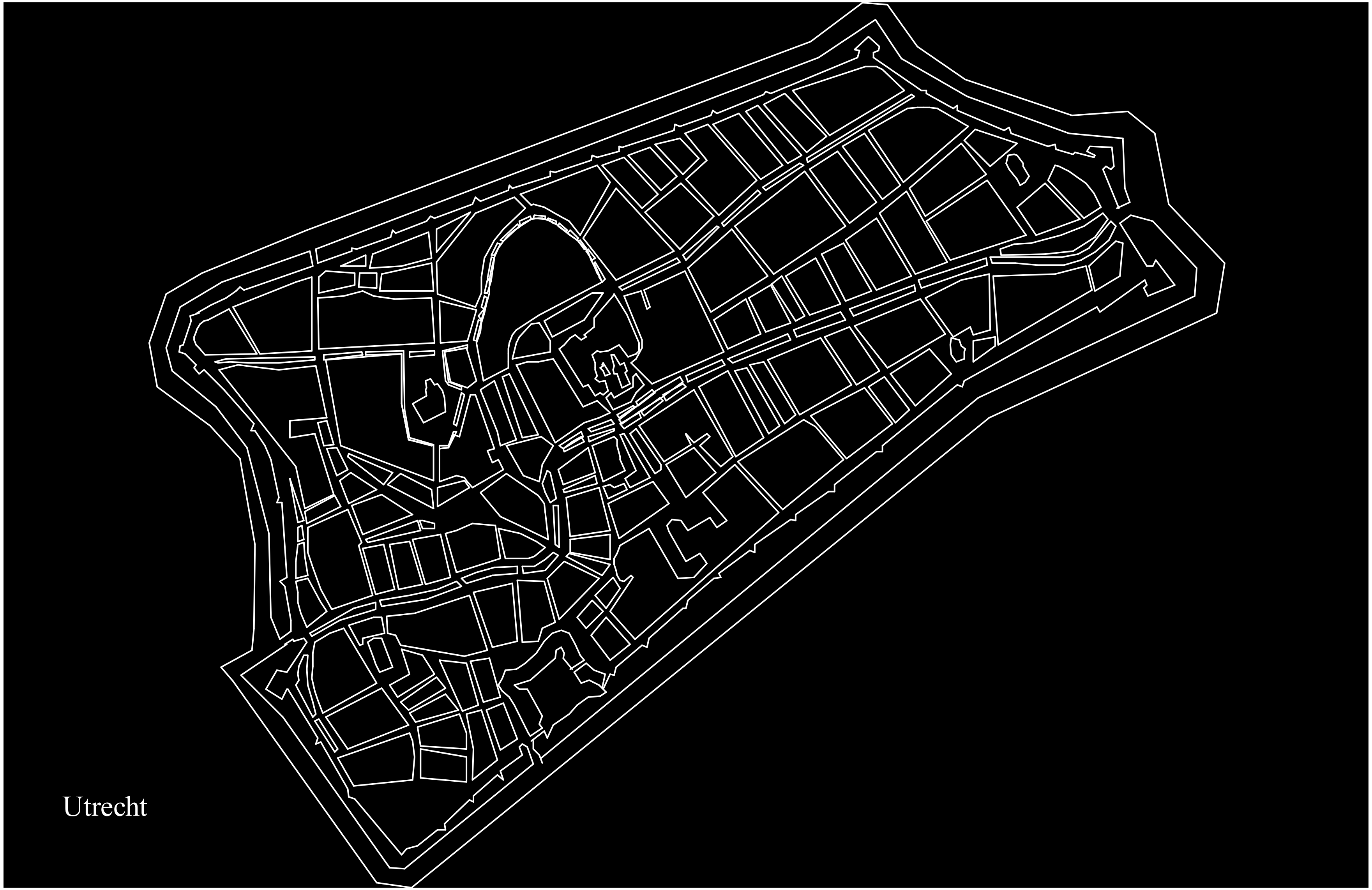


- These potentials can be calculated by two simple mathematical measures which reflect the two components of human movement: the *to-movement* component, by which we select a destination from and origin; and the *through-movement* component by which we select the sequence of spaces we pass through on the way from origin to destination.
- The *to-movement potential* of a space (in this case a street segment) can be calculated as the mathematical *closeness* of each space to all others. Left above shows the closeness of each segment to all others. Given only *distance decay*, though which people make more shorter and fewer longer trips, this measure must index the potential of each space as a *destination*, that is for *to-movement* from all other spaces. We call this the *integration* measure. The *through-movement* potential (top right) can be calculated by a measure of mathematical *betweenness*, that is the degree to which each segment lies on shortest paths between all pairs of spaces in the system. We call this the *choice* measure. (for mathematical details see Hillier & Iida 2005) In both cases the maths confirms the intuitions. We can measure the *to- and through-movement potential* of each spatial element in a complex.
- But both of course depend on the assumption that people will move by shortest paths. Do they ?

- To answer this we must know how to analyse real cities. First, how should we *represent* the street network of a city ? Space syntax begins by representing the network as a *least line map*, that is, the fewest straight lines that cover the whole network and make all connections. Why ? The simple answer is because it works – but also theoretically it can be argued that this is the *simplest* representation of the network: the smallest number of elements that in some sense describe the structure of the network and its connections.

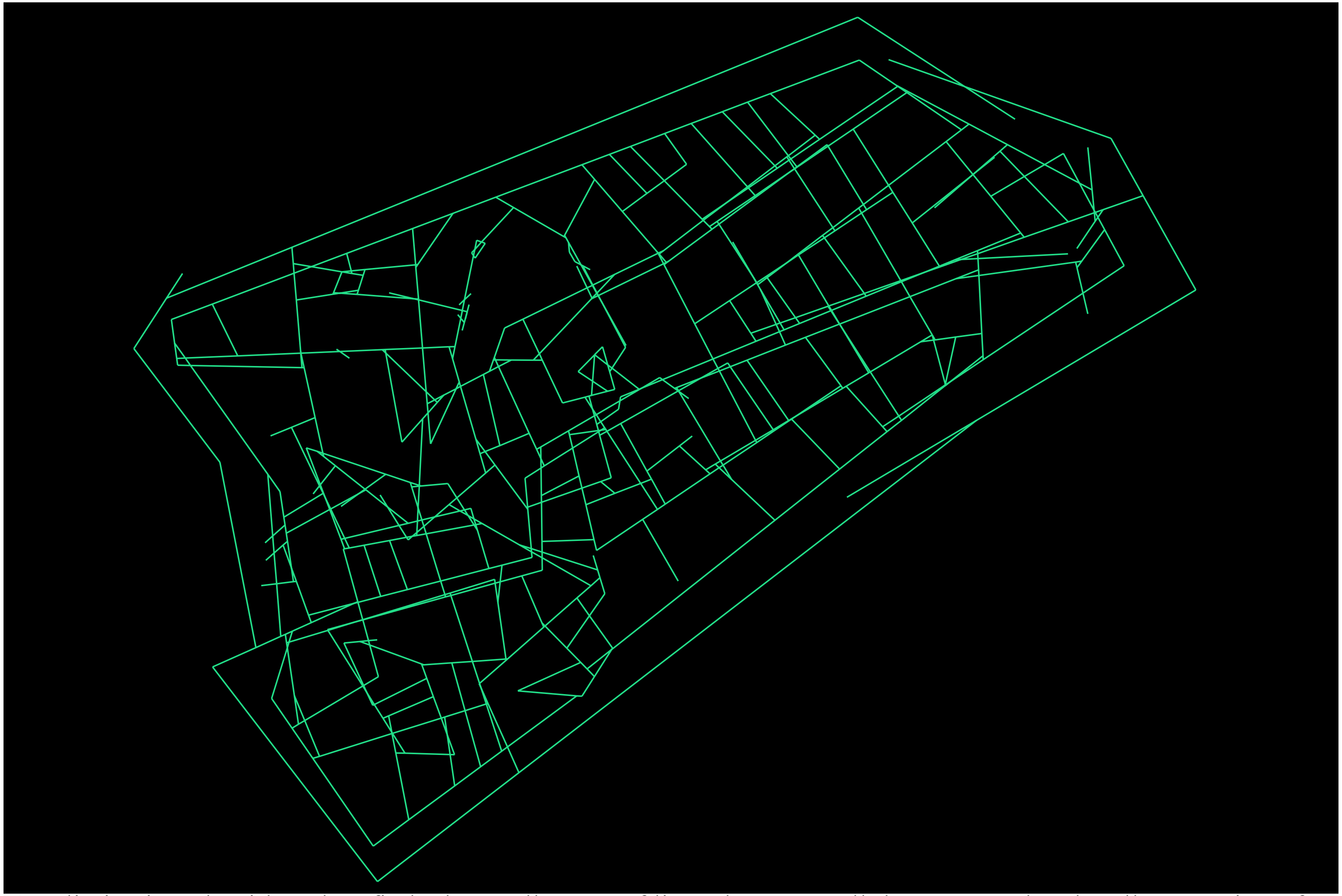
- What surprises some people is that we can then treat each line in the least line map as the node of a graph, with the intersections as links, the opposite of the common practice. But this give us a representation with both *topological* – the graph – and *geometrical* – the lines – dimensions of the city. We can think of the *least line graph* as a kind of *topo-geometric* representation of the street network. In fact, as we will see below, we use a more complex analysis of the least line map, but conceptually the least line map is fundamental to syntax.

- How then do we make a least line map ? Is there, as some have argued, some arbitrariness about them. I think not. Consider the following algorithm.



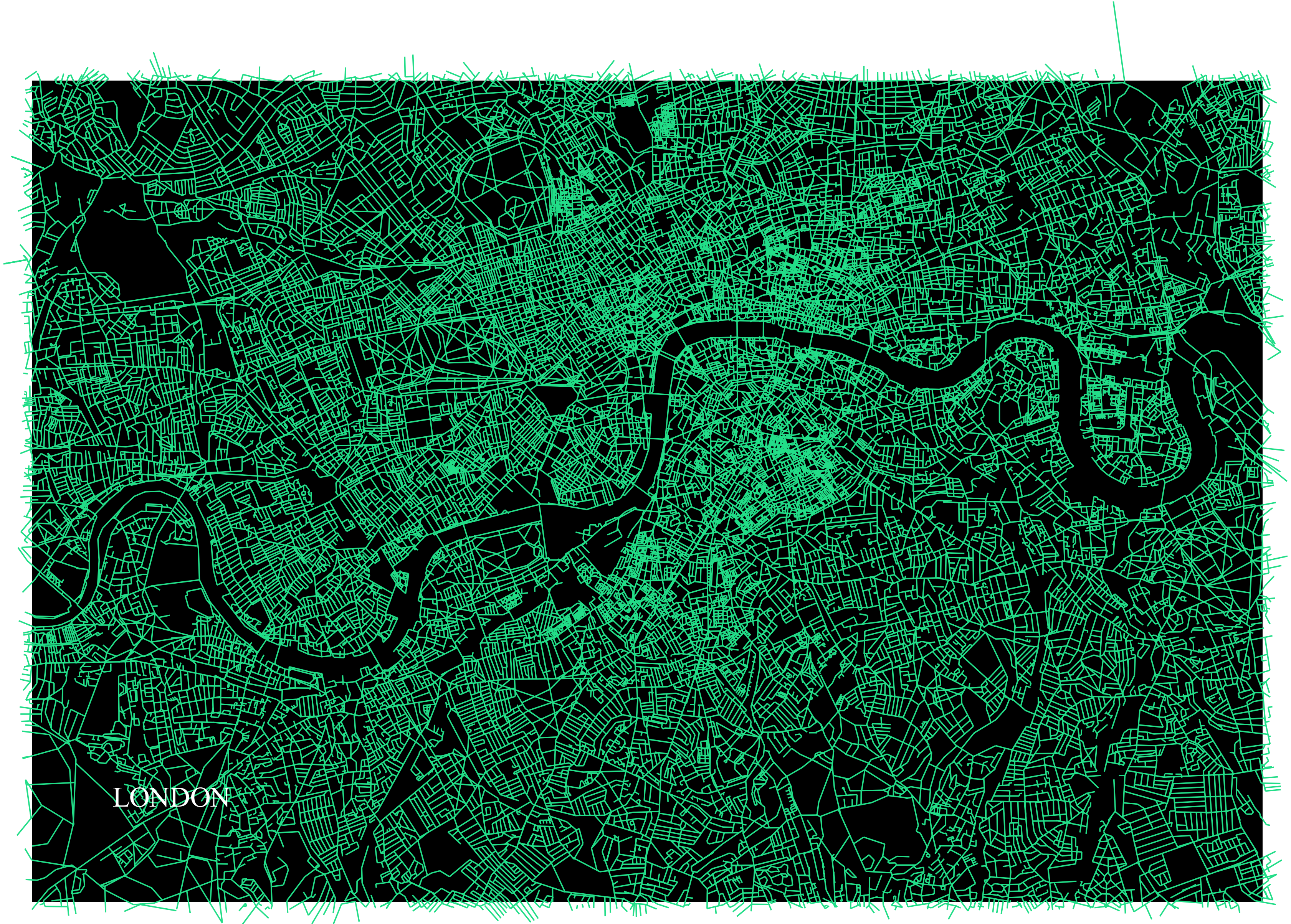
- We take the plan of a town, in this case medieval Utrecht.

- A piece of computer software called DepthMap, by Alasdair Turner of UCL, then finds all straight lines in the plan that are tangent to pairs of block vertices and extend from them, creating a dense array of lines we call an *all line map*. It describes all possible lines of movement with least distance and fewest turns. Bottom right you see what it looks like close to.

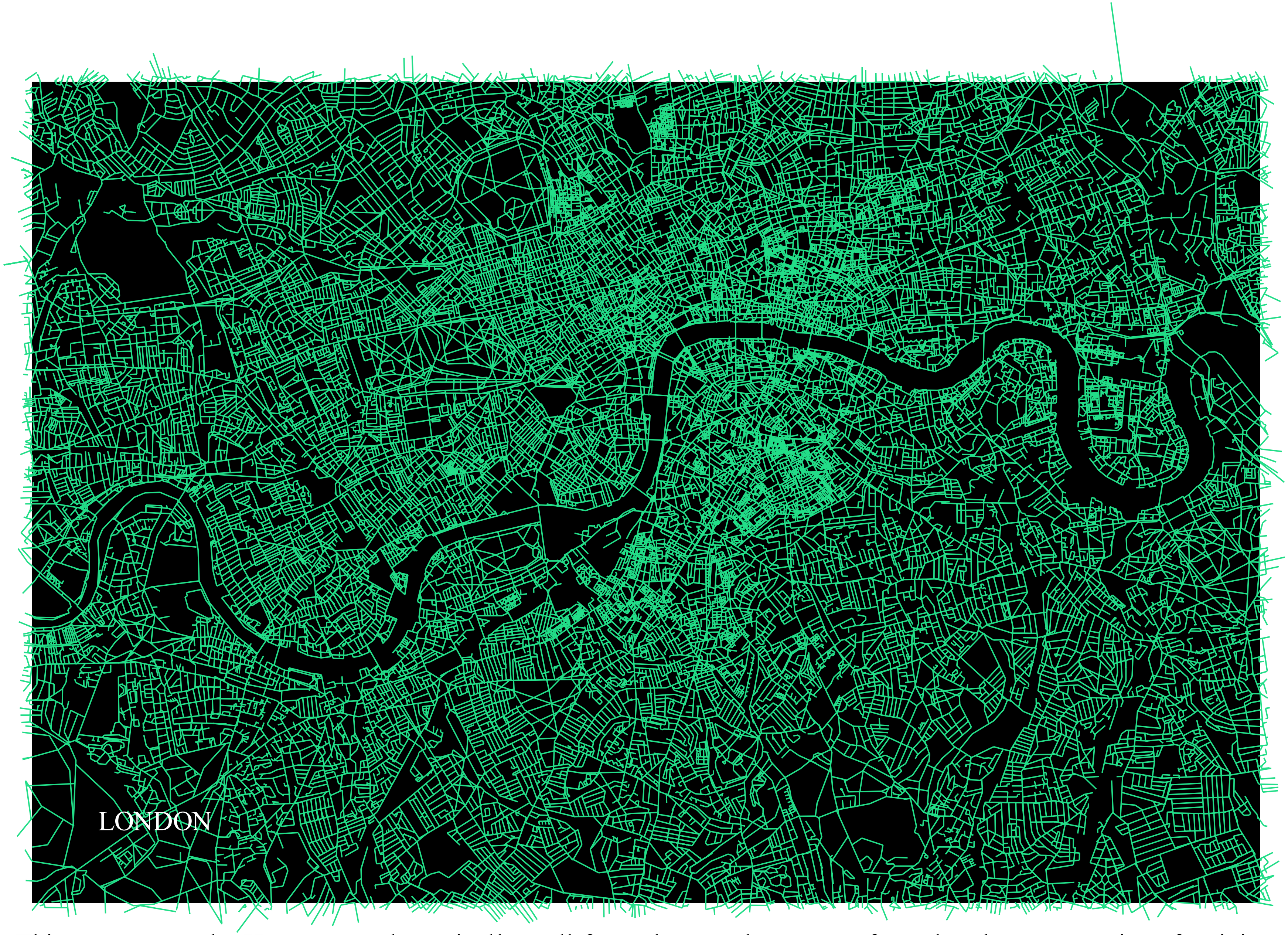


- An elimination algorithm then finds the smallest set of lines that cover all the space and make all connections from one line to another. If there is a direct line connecting two lines then it is part of the map. (Turner et al 2005) We call this the *Ieast line map* of a town plan. Because this is computationally prohibitive, in practice real least line maps are digitised by hand, and following a number of simple rules (Hillier & Penn 2004) ensures the same result.

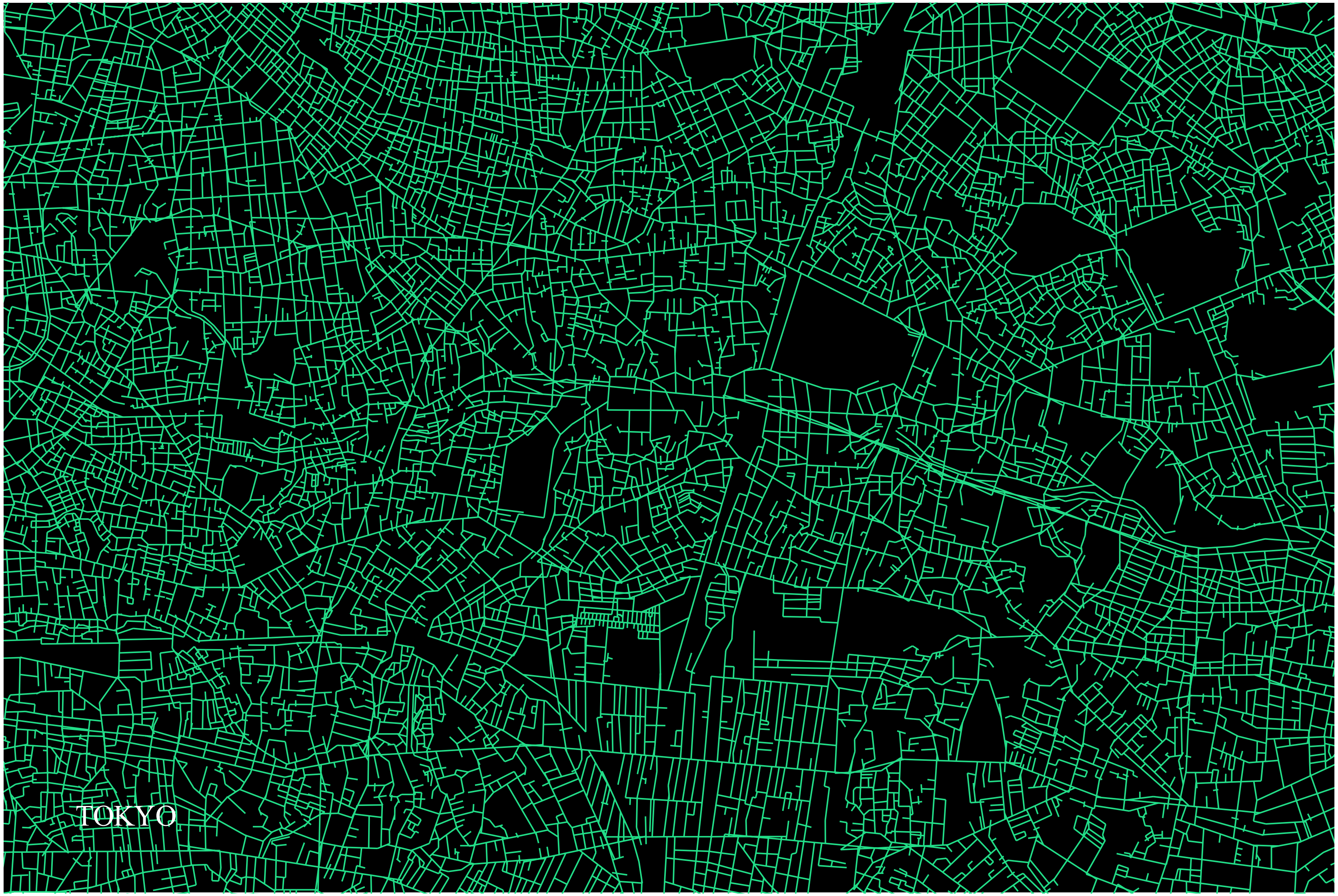
- Least line maps turn out to have some interesting properties, and to allow us to see others.



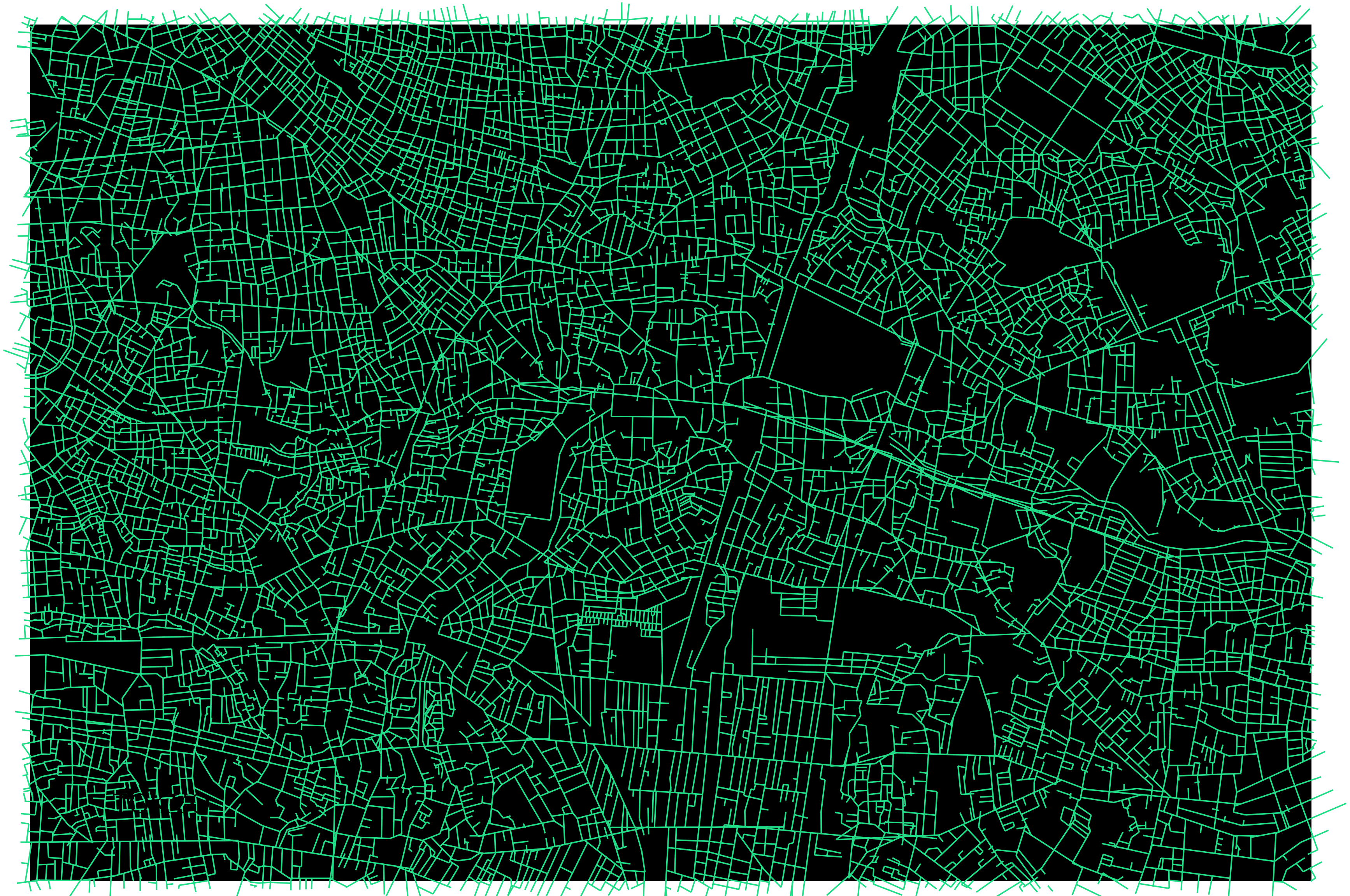
In fact, least line maps for real cities show some remarkable consistencies. At all scales, from the local area to the whole city, we find cities are made up of a very small number of long lines and a very large number of short lines, so much so that in terms of the line length distributions in their least line maps cities have *scale-free* properties (Carvalho & Pennn 2004). This means that wherever we are, we are not far from a line much longer than the one we are on. Formally, it means that these seemingly haphazard growths have acquired some mathematical structure.



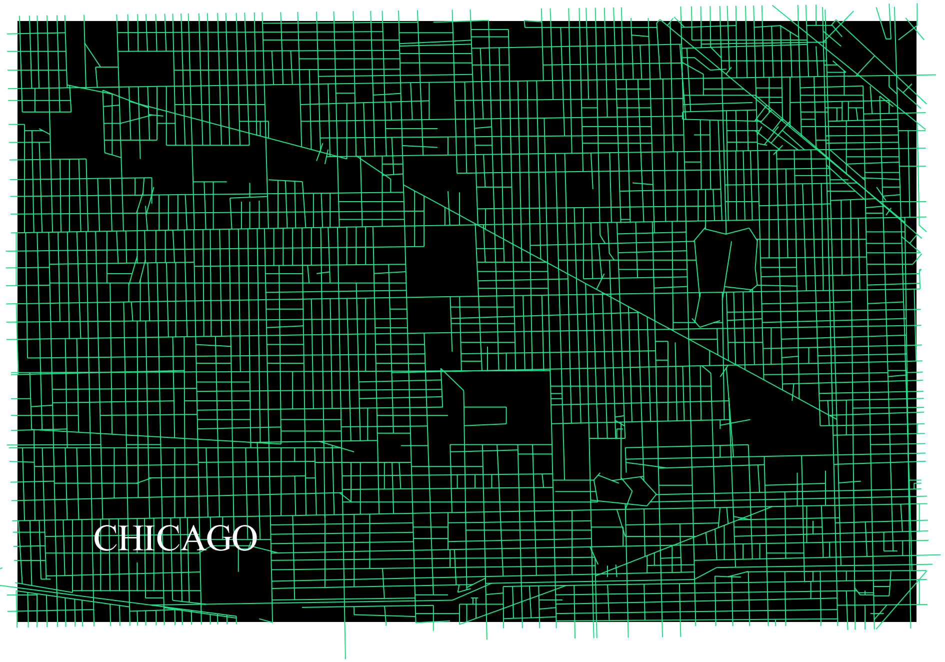
This poses a puzzle. How can mathematically well-formed networks emerge from decades or centuries of activity by innumerable uncoordinated agents acting in very different social, economic and cultural situations and working with very different, and highly variable, geometries ?



This is not all we find. If we look carefully at organic grids, we begin to find some geometry. Looking at the least line map, we intuitively we pick out line continuities. What we are seeing are lines joined by nearly straight connections. If we move along one of these we are very likely to find another at the end of the line, and then another. This happens at all scales, but at each scale the lines are locally longer than lines which lack this kind of angular connection. We can say the longer the line, the more likely it is to end in a nearly straight connection to another line.

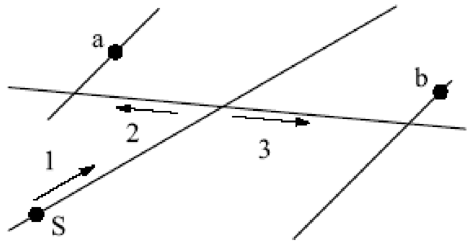


- We also see a large number of shorter lines with near right angle connections, forming local grid like patterns. Again if you find one then it is likely that there will be several others in the immediate neighbourhood. We can also say the shorter the line, the more likely it is to end in a right angle or near right angle. These are the opposite properties to those we find in highly formal cities, like Brasilia or pre-Columbian Teotihuacan, where the longest lines end at right angles on the most important buildings. But most organic grids have the opposite properties.

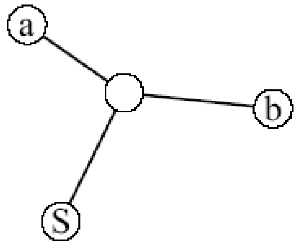


- So organic grids tend to have a kind of *fuzzy* or *probabilistic geometry*. They are more regular than they look at first sight. There is, in effect, a *hidden geometry* in organic cities: they are quite grid like, in spite of seeming irregular. (Hillier 1999) We can call them *deformed grids*. At the same time, geometric grids are not so regular. Chicago is just as fractal in its line length organisation as, say, Isphahan. Lines are of very different lengths and connectivities, because many are *interrupted*, either by buildings or other artefacts. We can speak of two kinds of grid: *deformed* grids and *interrupted* grids.

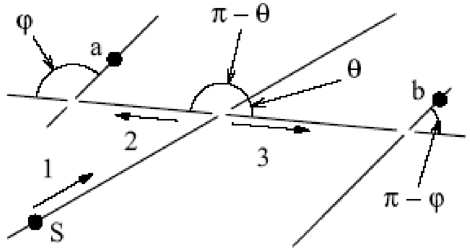
- But both kinds seem to have a *dual structure* made up local, more grid like *patches*, and globalising, more linearised sequences of lines forming *larger scale alignments*, and linking the patches into the larger scale system. So how can we analyse these curious, but seemingly well-formed, *dual* geometrical objects in order to investigate their structure and structure-function relations.



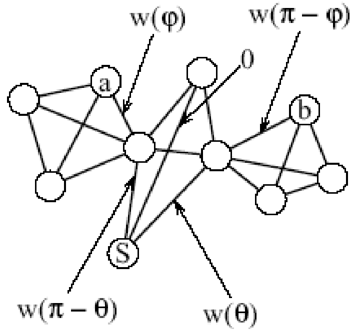
(a) line model



(b) graph of (a)

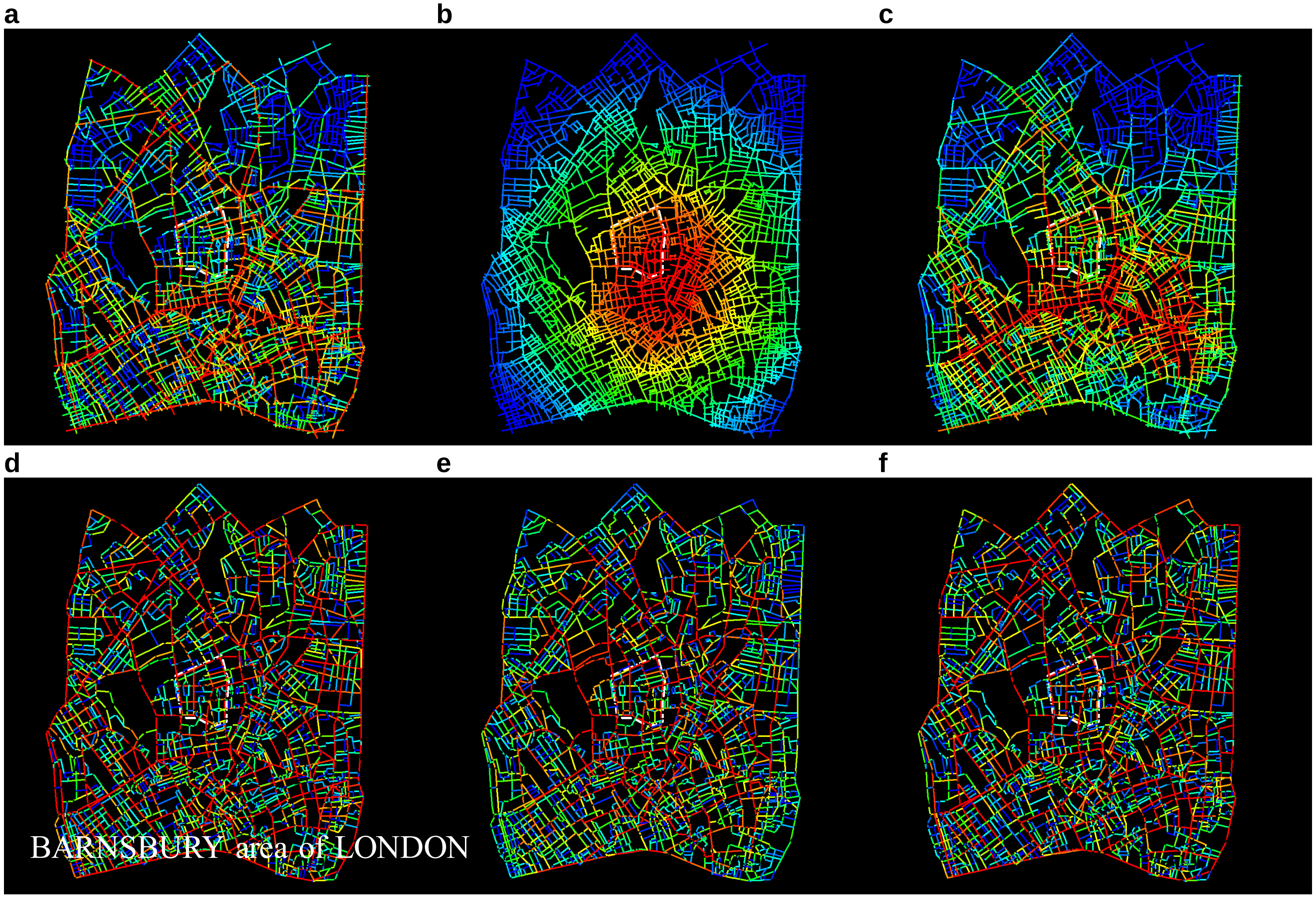


(c) segment model



(d) graph of (c)

- First some methodology. Starting from the *least line map,* we divide each line into its *segments* (between intersections) and represent the result as a graph. We then assign *integration (closeness* in mathematical parlance) and *choice (betweenness* in maths*)* measures using *shortest path (metric), least angle change (geometric), fewest turns* (*topological)* weightings to relations between each segment and all others, and we apply them at different *radii* from each segment, also defining radii metrically, geometrically and topologically. This yields a matrix of configurational measures which we can use to see if we can find significant structure-function relations. So we can look at each segment in a system in terms of either its *to or through movement potential*, defining *distanc*e and *radius metrically* (shortest paths), *geometrically* (least angle change paths) or *topologically* (fewest turns paths) (Hillier & Iida 2005) reflecting the different ways in which paths through the system might be defined.



- With this matrix of measures we can solves an interesting problem that has long troubled cognitive science: how do people navigate in complex spatial systems like urban grids ? This will depend, among other things, on how people make *distance* judgements in complex space ? So how? Shortest paths? Fewest turns? Least angle change?

- So we apply the three weightings to the two measures to make six different analyses of the same urban system, and correlate the resulting patterns of values for each segment with observed movement flows on that segment. If across cases there are consistently better correlations with one or other weighting, then the only logical explanation would be that this weighting reflects better how people are biasing spatial movement choices, since everything else about the system is identical.

*VEHICULAR MOVEMENT r^2 values for correlations between vehicular flows and shortest path, least angle and fewest turns analysis applied to accessibility and choice measures. Best correlations are marked *. Numbers in brackets indicate best radius in segments for accessibility measures.*

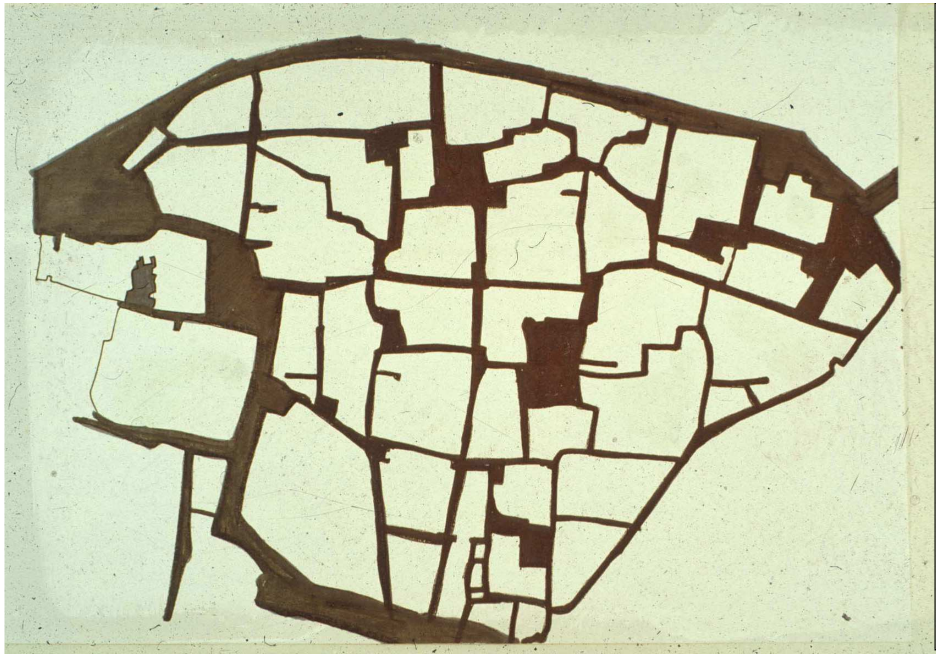
	Gates		*Measure*	*Least Length*	*Least angle*	*Fewest turns*
BARNSBURY	116		accessibility choice	.131(60) .579	.678(90) .720*	.698(12) .558
CALTHORPE	63		accessibility choice	.095(93) .585	.837*(90) .773*	.819(69) .695
SOUTH KEN	87		accessibility choice	.175(93) .645	.688(24) .629	.741*(27) .649
BROMPTON	90		accessibility choice	.084(81) .475	.692*(33) .651*	.642(27) .588

- In fact, across four separate studies of both pedestrian and vehicular movement patterns, we consistently found that *geometric*, or *least angle* weightings yields the strongest movement prediction, with an average of around .7 for vehicular movement and .6 for pedestrian, closely followed by the topological or fewest turns weighting. Metric shortest paths are markedly inferior in most cases, and in general, to-movement potentials are slightly stronger than through-movement potentials, though both are strong (Hillier & Iida 2005).

*PEDESTRIAN MOVEMENT r^2 values for correlations between pedestrian flows and shortest path, least angle and fewest turns analysis applied to accessibility and choice measures. Best correlations are marked *. 'a' or 'c' for combined multiple values indicates whether accessibility or choice is dominant. Numbers in brackets indicate best radius in segments for accessibility measures.*

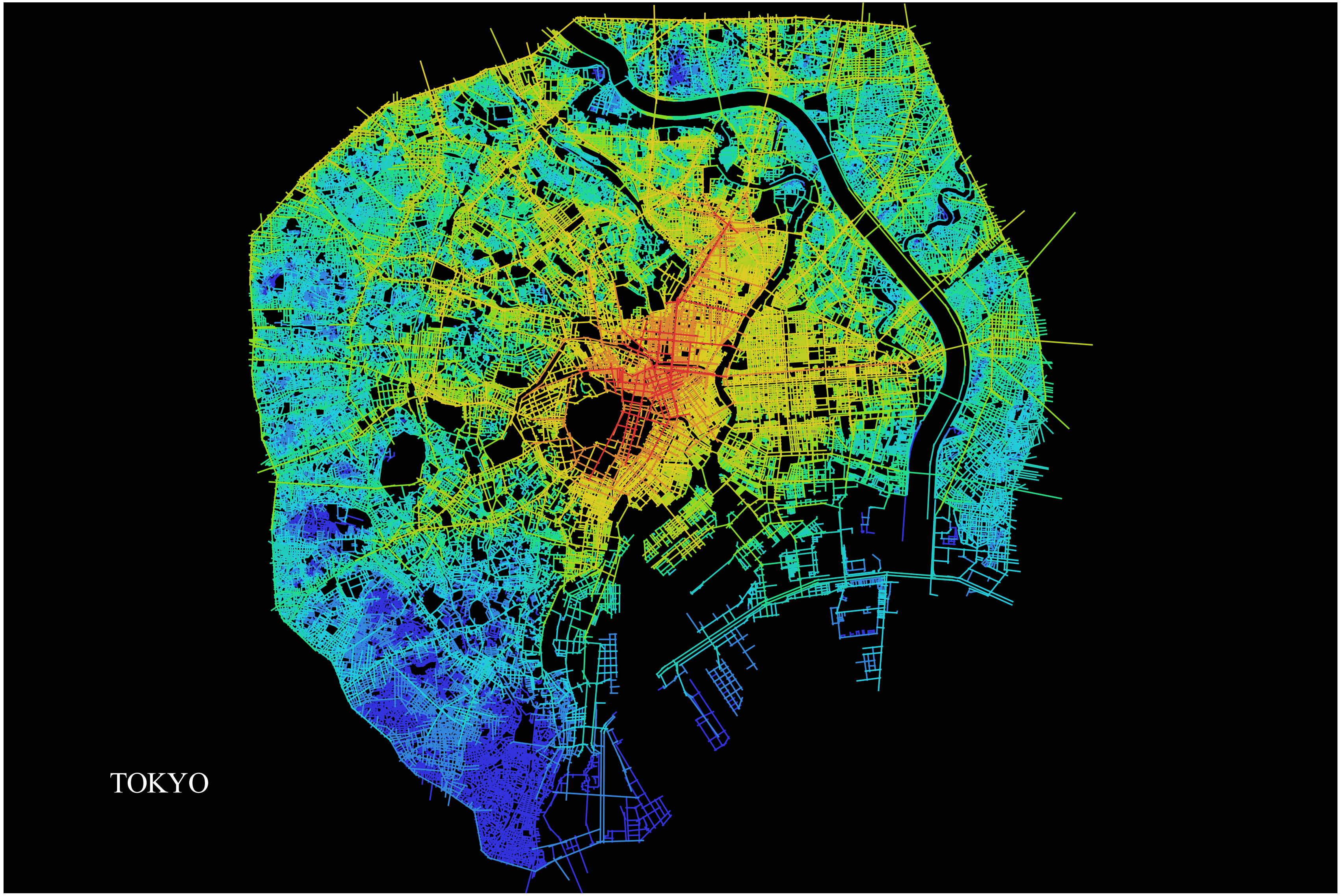
	Gates		*Measure*	*Least length*	*Least angle*	*Fewest turns*
BARNSBURY	117		accessibility choice	.119(57) .578	.719*(18) .705	.701(12) .566
CALTHORPE	63		accessibility choice	.061(102) .430	.637(39) .544*	.624*(36) .353
SOUTH KEN	87		accessibility choice	.152(87) .314	.523*(21) .457	.502(15) .526*
BROMPTON	90		accessibility choice	.111(81) .455	.623*(63) .513*	.578(63) .516

- This shows that configurational factors to do with the network are responsible for a substantial part of movement flows in two senses:
  - the objective *to- and through-movement potentials* of the network itself contributes what we might call *network effects* on shaping flows;
  - these are modified by how human *minds contribute distance effects* through how they read distance in complex spaces (Hillier & Iida 2005).

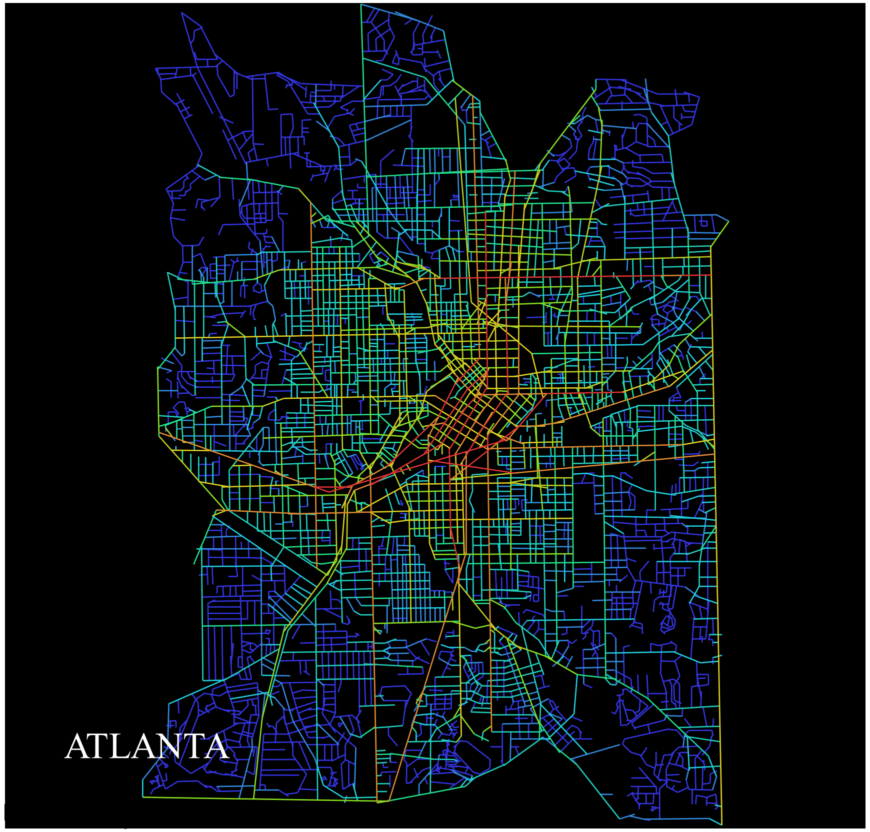


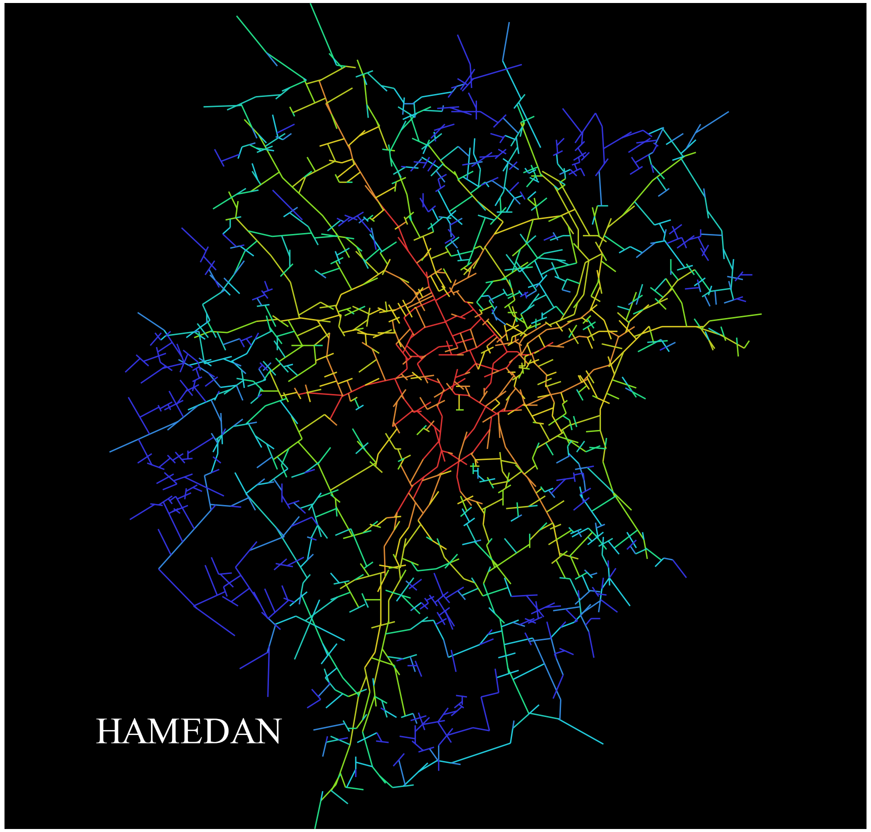
So we have brought to light two rather remarkable things. The first is that the grid configuration itself is largely responsible for the pattern of movement flows along streets. We call this the theory of *natural movement*. Natural movement is the proportion of movement flows due to the *structure* of the urban grid rather than to specific *attractors*. Second, the way we navigate spatially is not guided by metric distance as has been assumed, but by geometrical and topological factors. With this knowledge, then, we have a new tool for investigating the form and functioning of cities.

First let us look at the emergent spatial form of cities. Applying the *integration*, or *to-movement* measure to real cities, and using the least angle change, or geometrical, definition of distance, we find some remarkable emergent geometrical patterns, and again we find they are near invariant across different kinds of city. Mapping strong integration in red through to blue for weak, we find a pattern we call a *deformed wheel*: a hub, spokes and rim forming the main structure of public space, and the more residential areas in the interstices of the wheel. This first came to light in the study of small towns in the South of France. We found the same pattern in London's urban areas with her 'urban villages' at the hub.

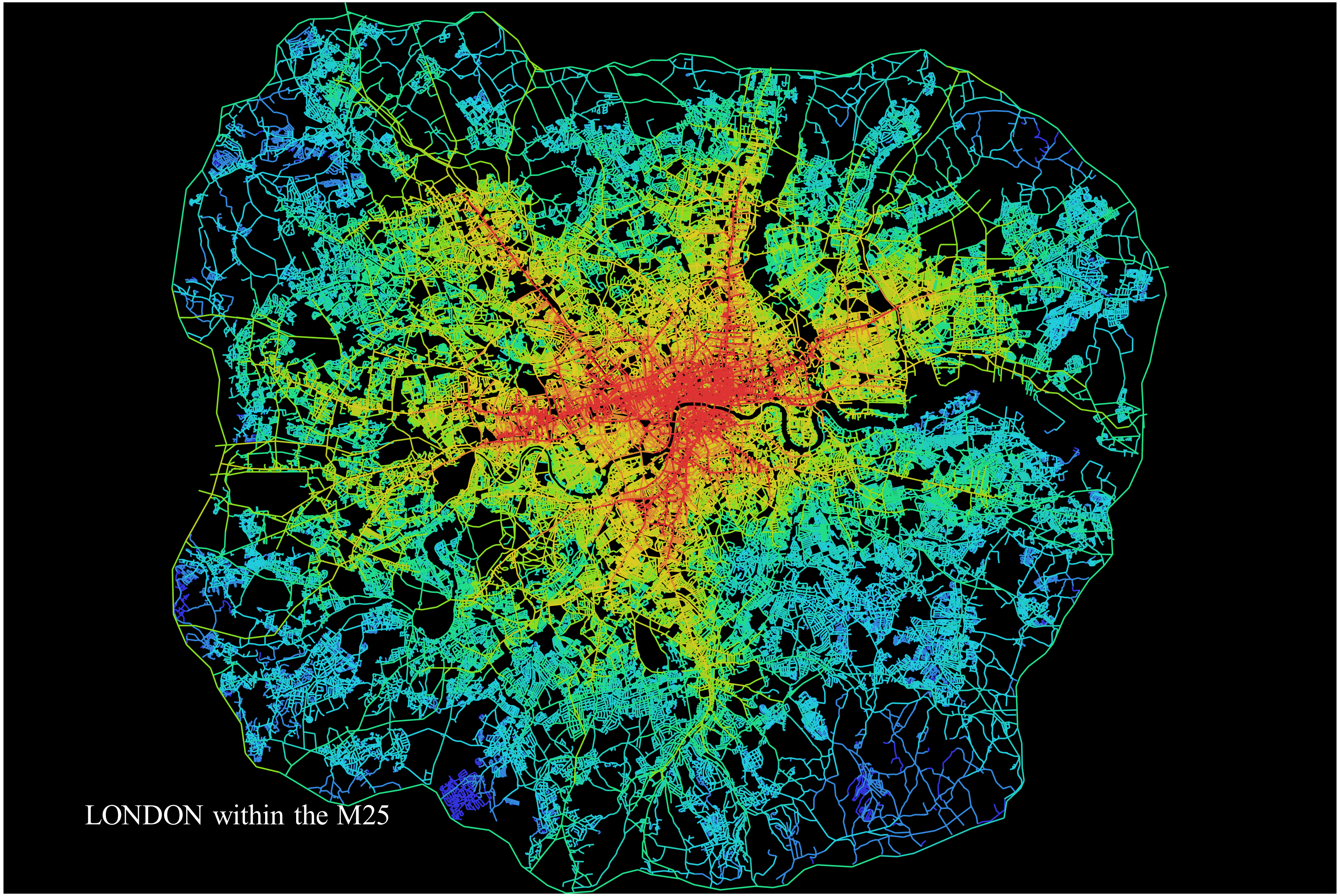


• So it was something of a surprise to find the same pattern in metropolitan Tokyo, but this time with multiple rims

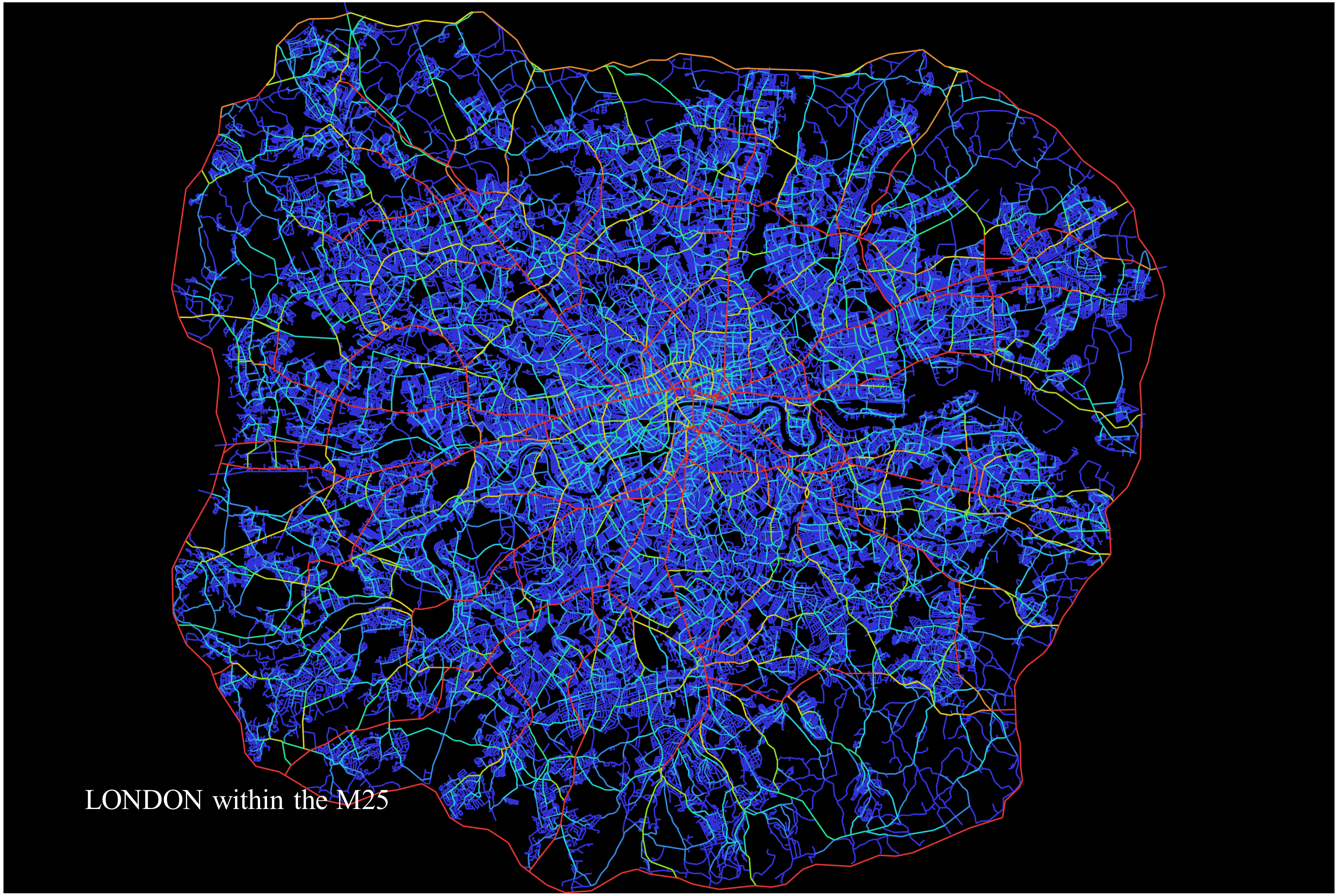




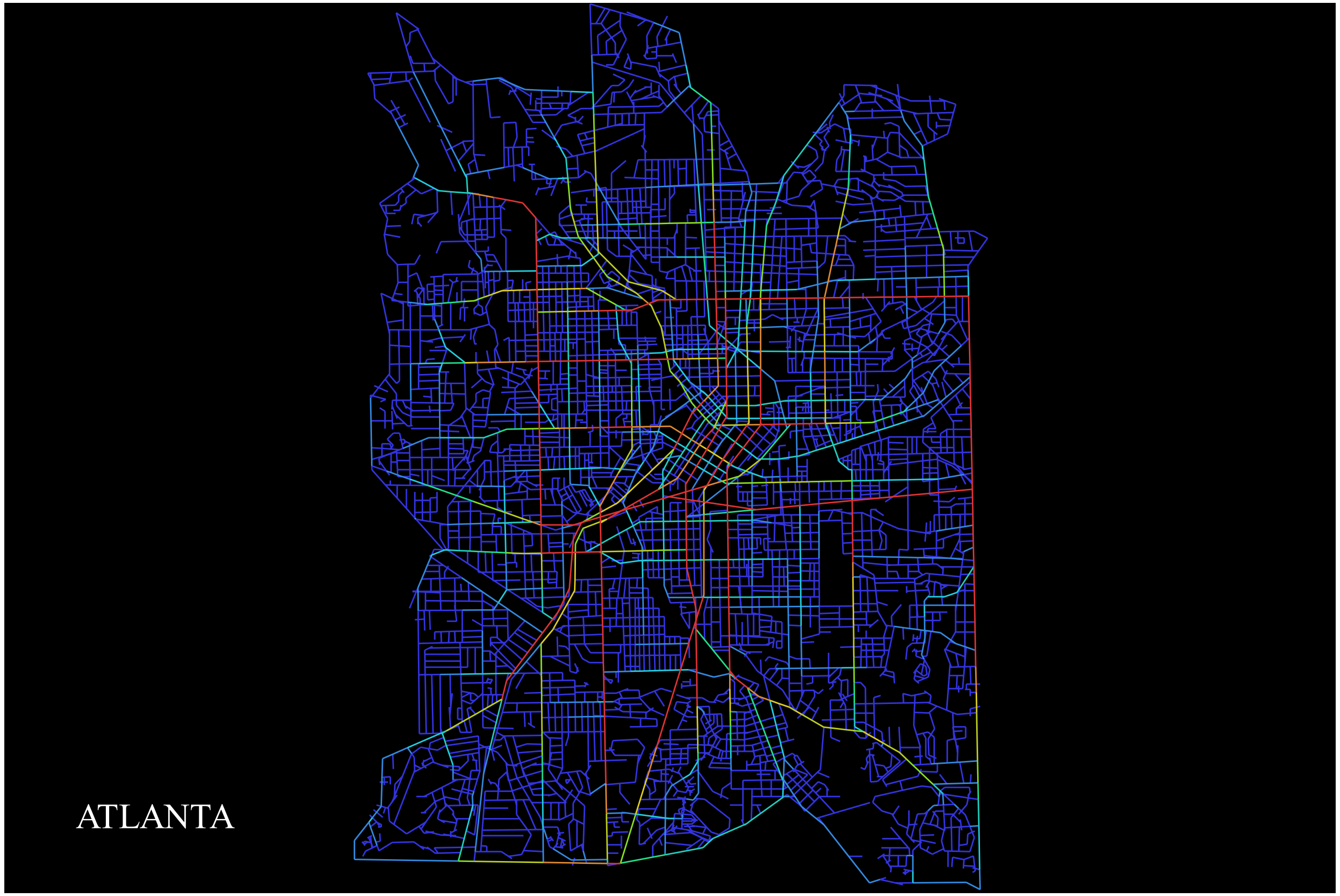
- We seem to find this pattern emerging under very different geometric conditions. For example, in spite of its strong underlying grid we find this emergent structure in Atlanta on the left and very ungeometric Hamedan in Iran on the right.



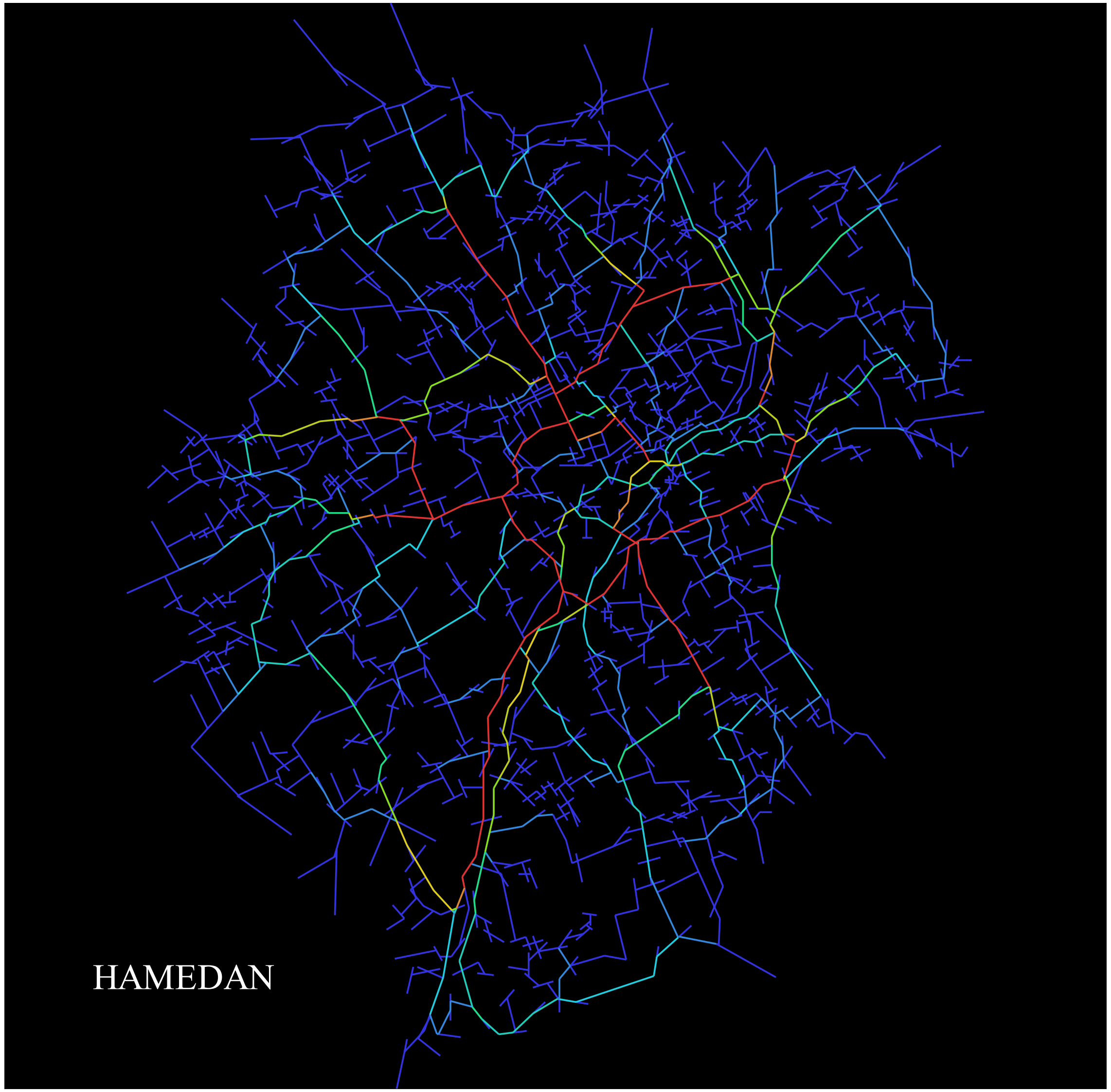
- And in the most organic of western cities: London.



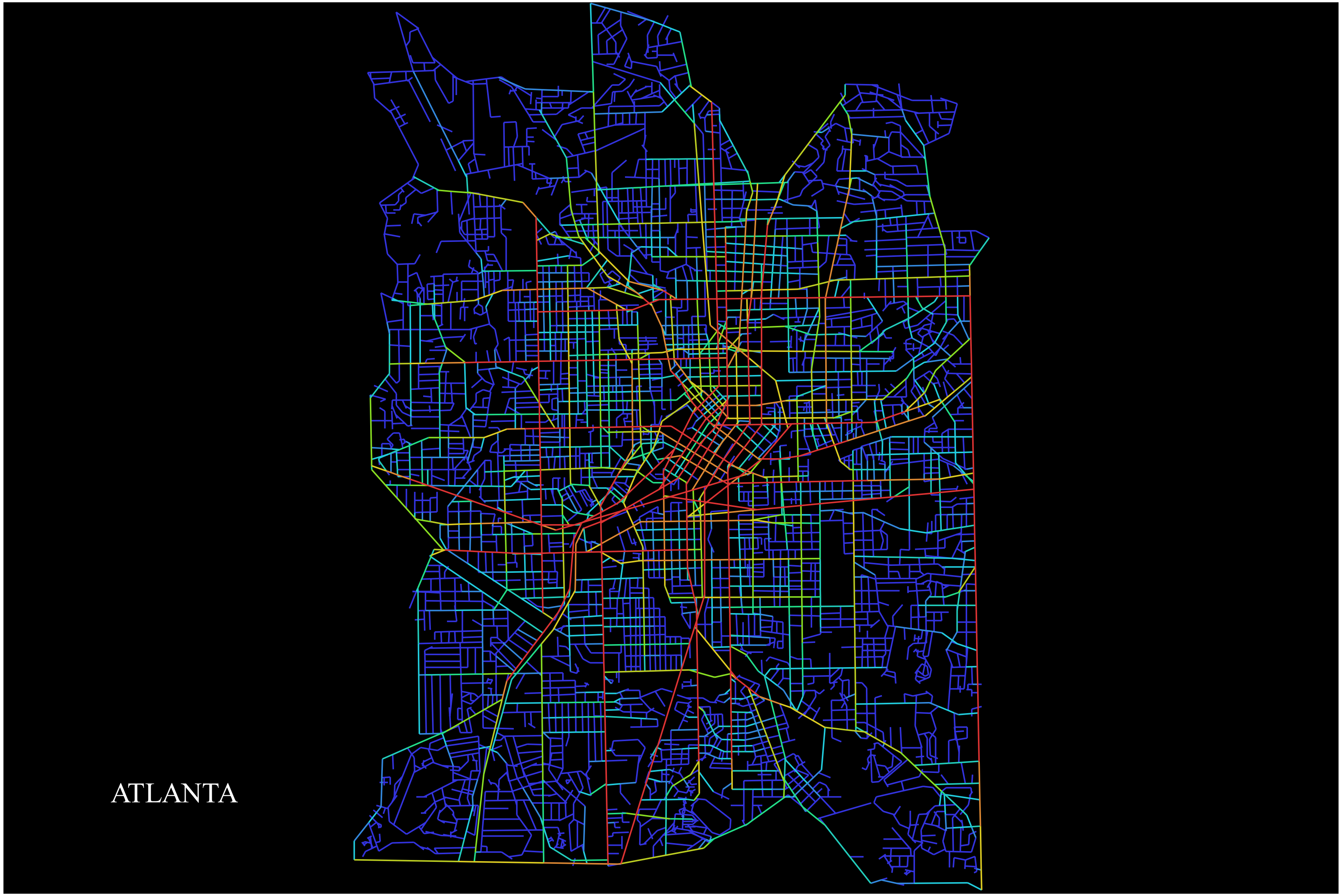
- When we apply the *choice*, or *through movement* measure, we find a different kind of structure reflecting some of the deformed wheel but more like a *network*.



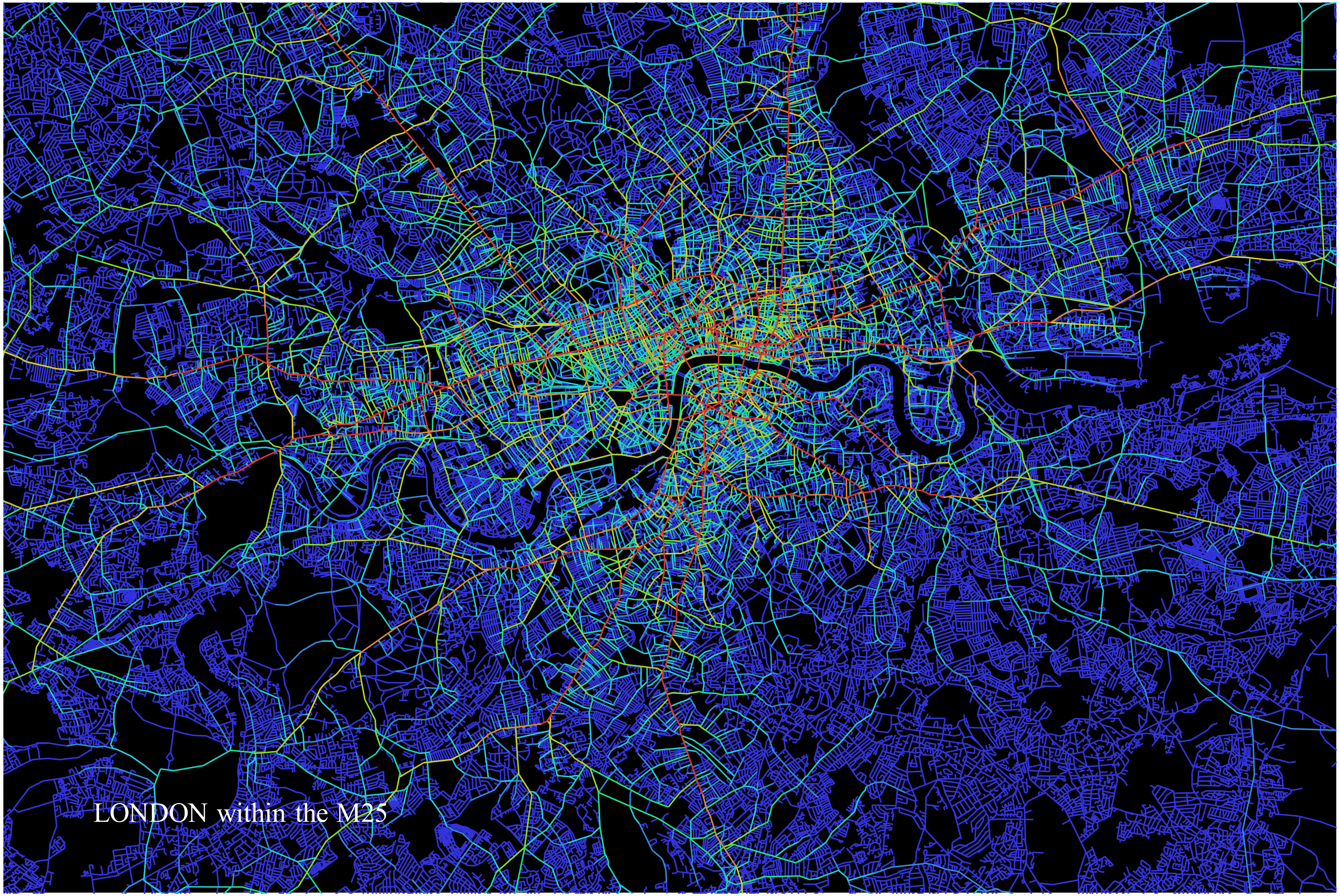
- Again, this seems to work for geometric interrupted grids such as Atlanta.



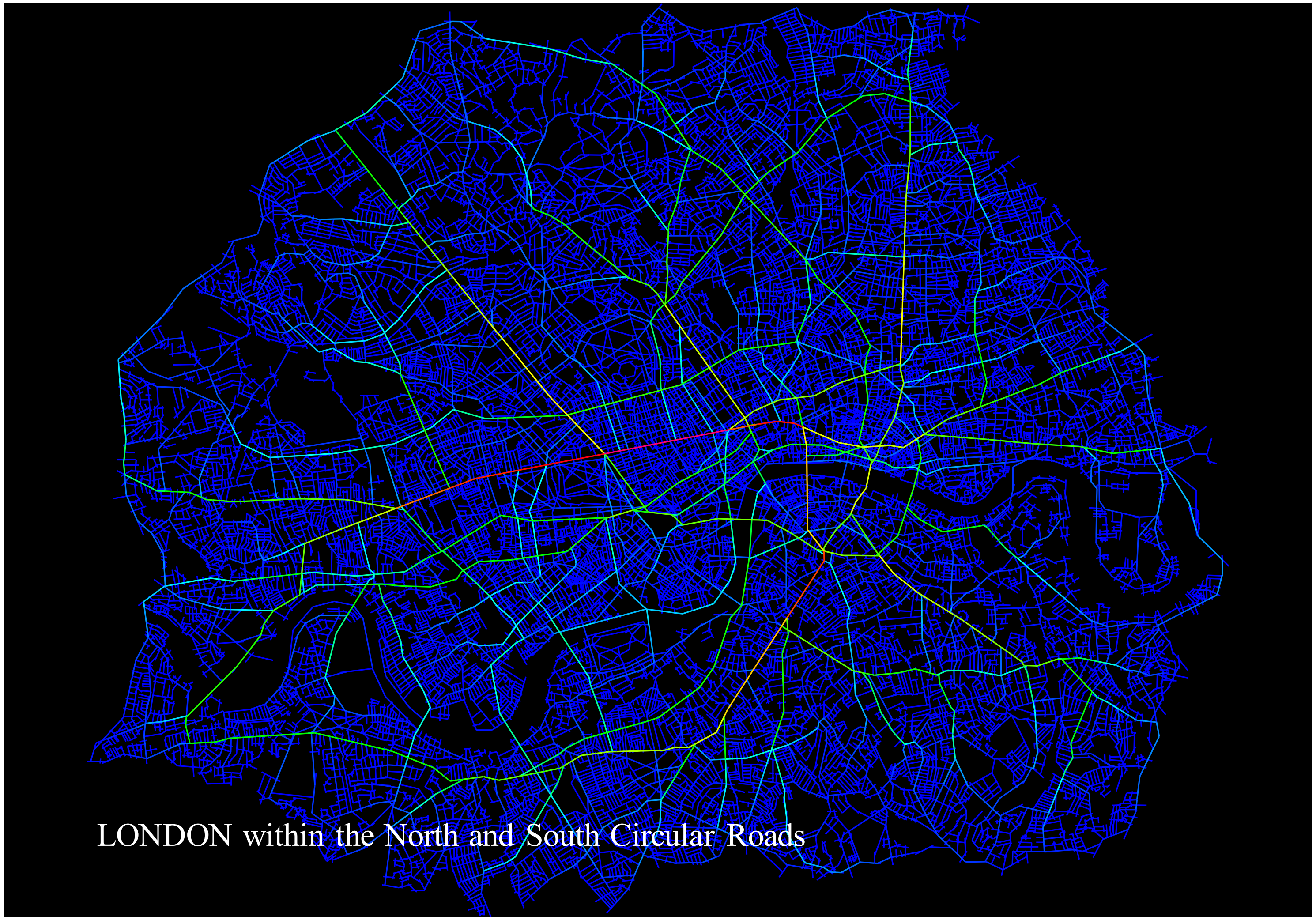
And for the irregular geometry of Hamedan



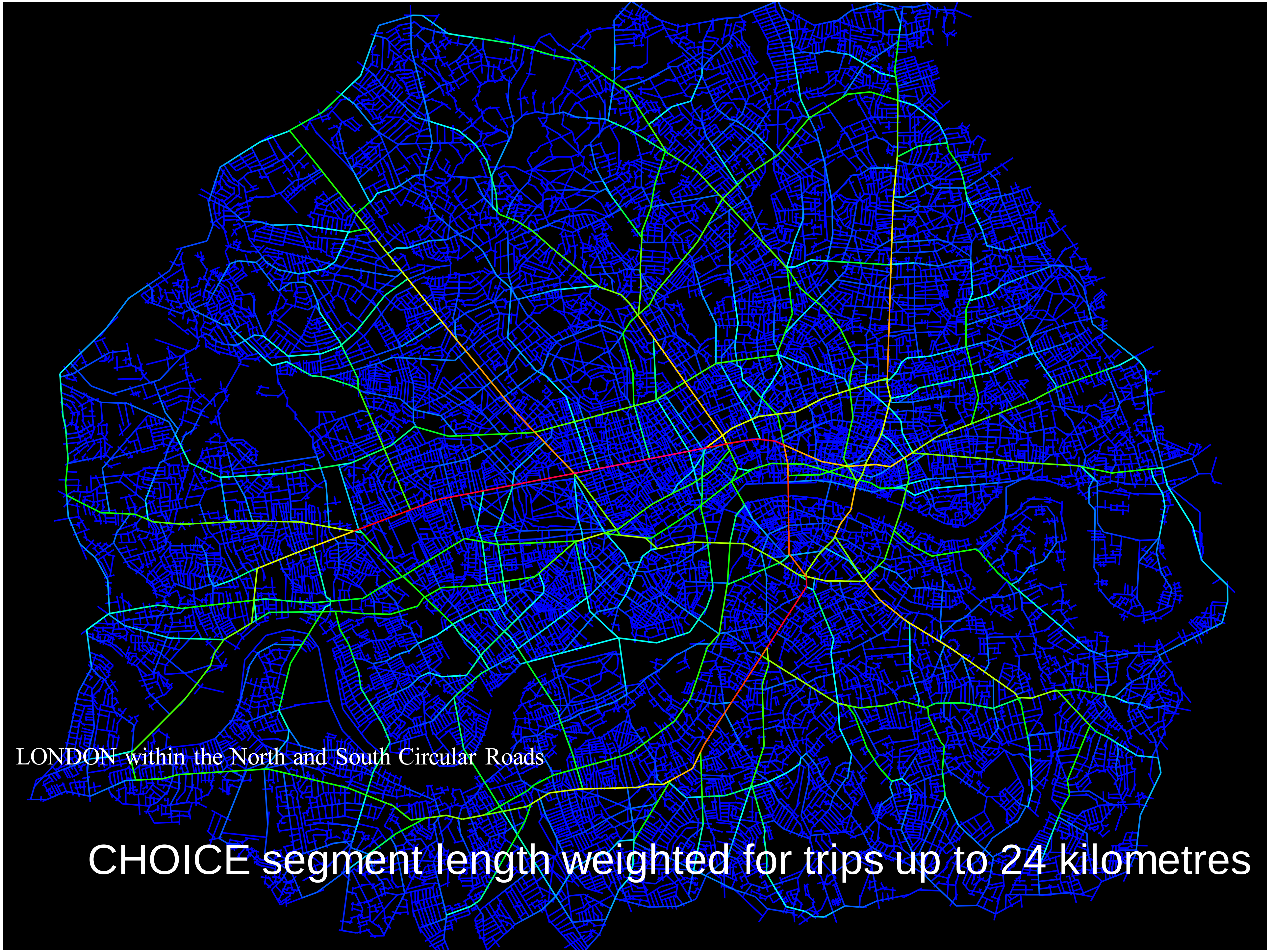
- We can also combine the two measures by simply multiplying one by the other, to give a combined picture of the to and through movement potentials of each street segment in the system with respect to all others, as in Atlanta.

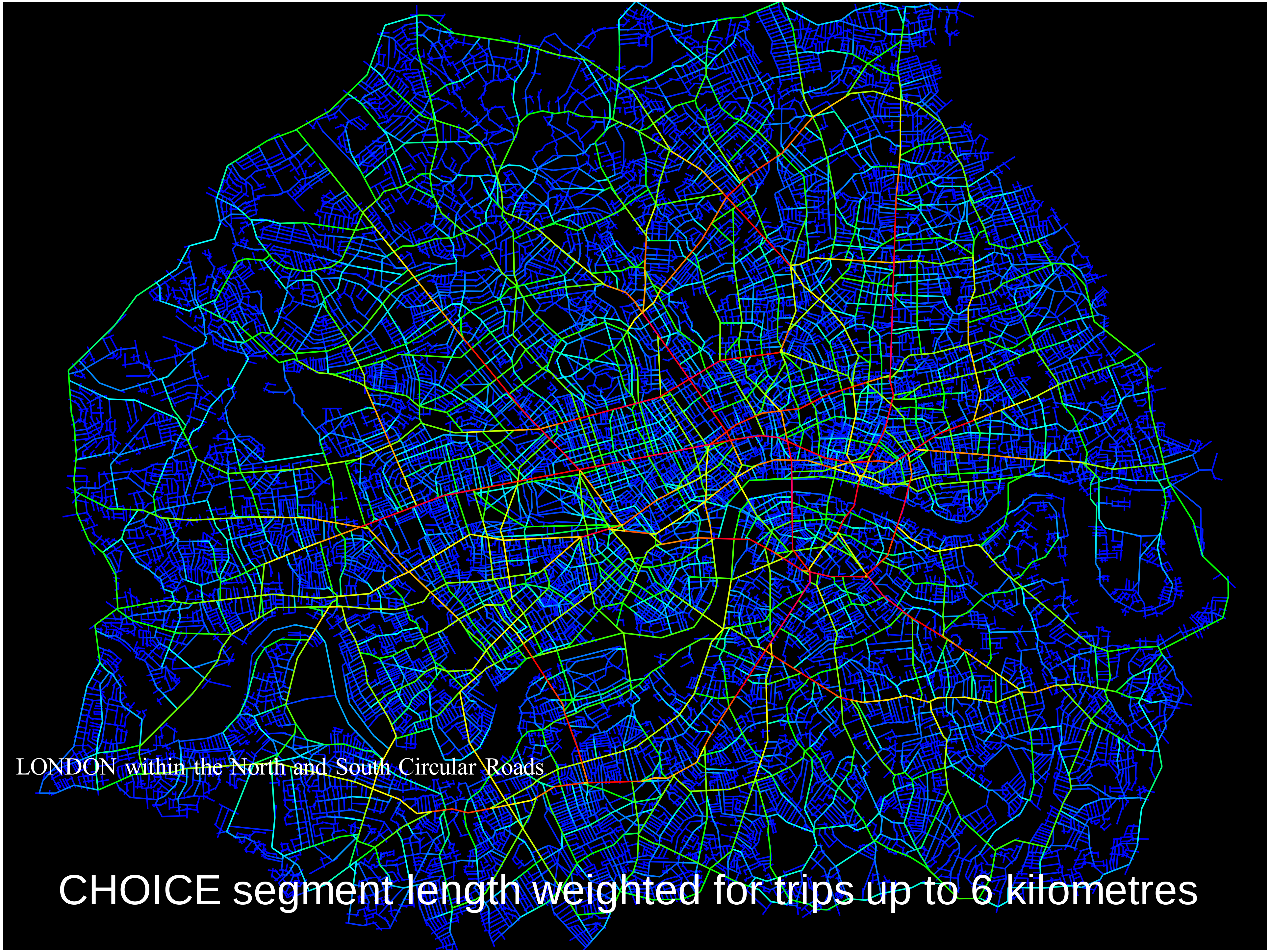


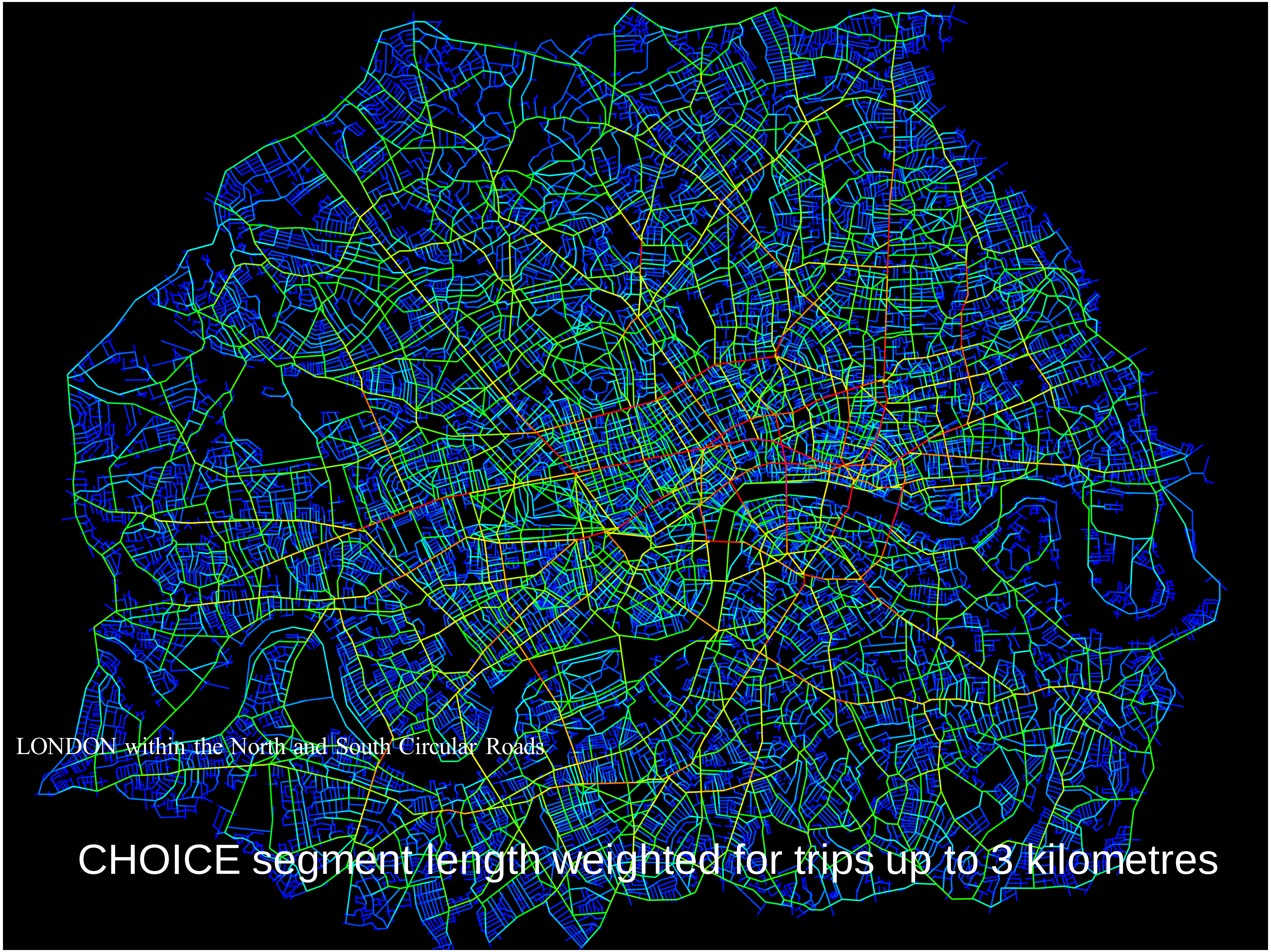
Or the central areas of London. These analyses are amazingly suggestive both in terms of what we know about the functional structure of London – where all the shopping streets are for example, and also from the point of view of our cognitive models of London. We will look at this in a moment.

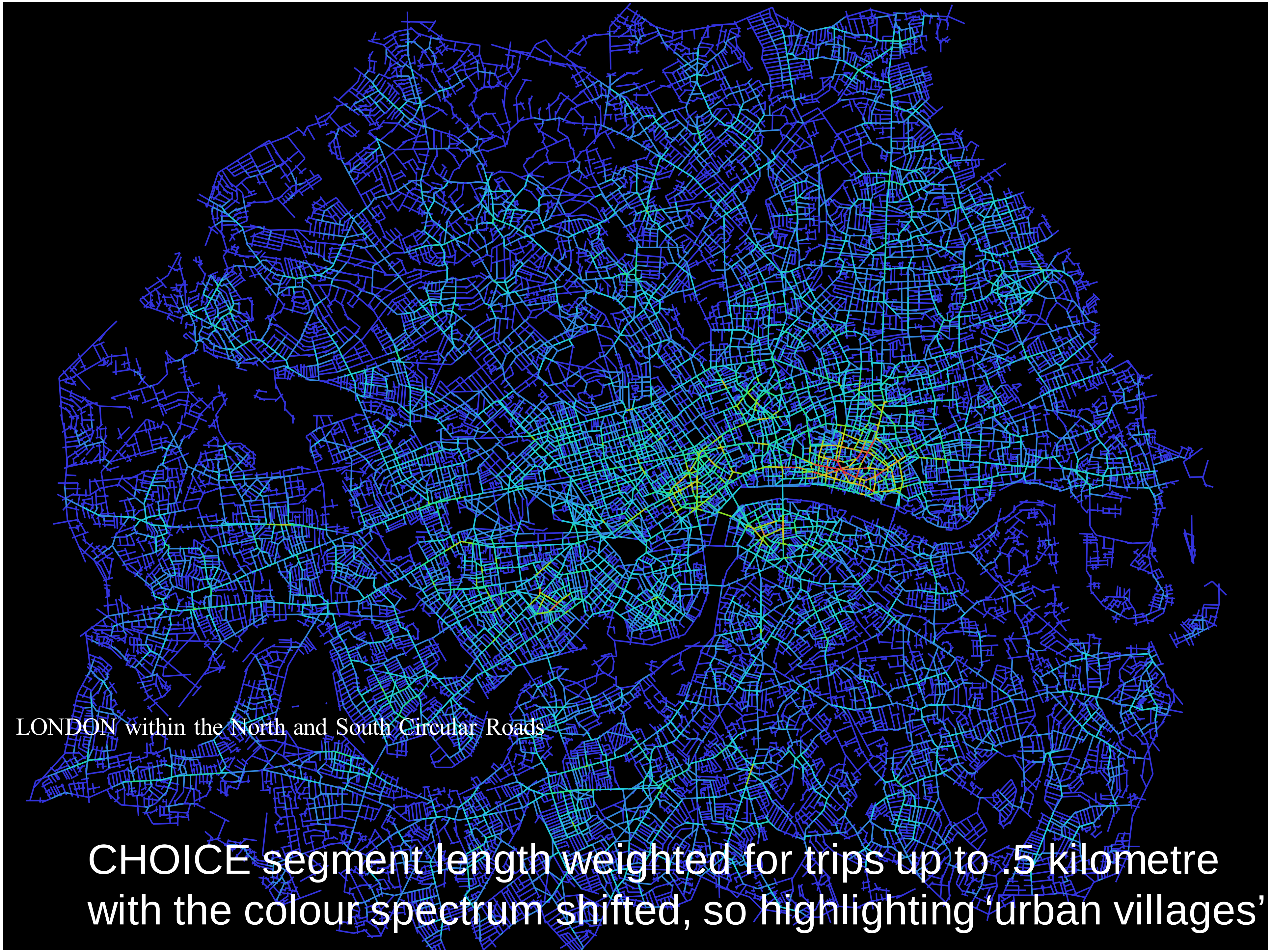


But before we do this, we must consider another important dimension: the *radius* of the measures. This will allow us to capture much more detail of local structure, reflecting the fact that when we make large scale trips in the city we tend to use the global structure, but when we move locally we will often find ourselves prioritising spaces which are not part of global routes, but are locally important. Consider the following sequence in which we reduce the radius of our analysis of London, and we will see spaces becoming more and less important as we do so.


LONDON within the North and South Circular Roads
CHOICE segment length weighted for trips up to 24 kilometres


LONDON within the North and South Circular Roads
CHOICE segment length weighted for trips up to 6 kilometres


LONDON within the North and South Circular Roads
CHOICE segment length weighted for trips up to 3 kilometres



CHOICE segment length weighted for trips up to .5 kilometre
with the colour spectrum shifted, so highlighting ‘urban villages’

- We can now use the colour range as a kind of microscope to explore very detailed local patterns. Above, we zoom in on the area of north west London and find that at a radius of about 1000 metres all the urban villages, with their groups of local shops, are highlighted in red against the background of the more residential areas.

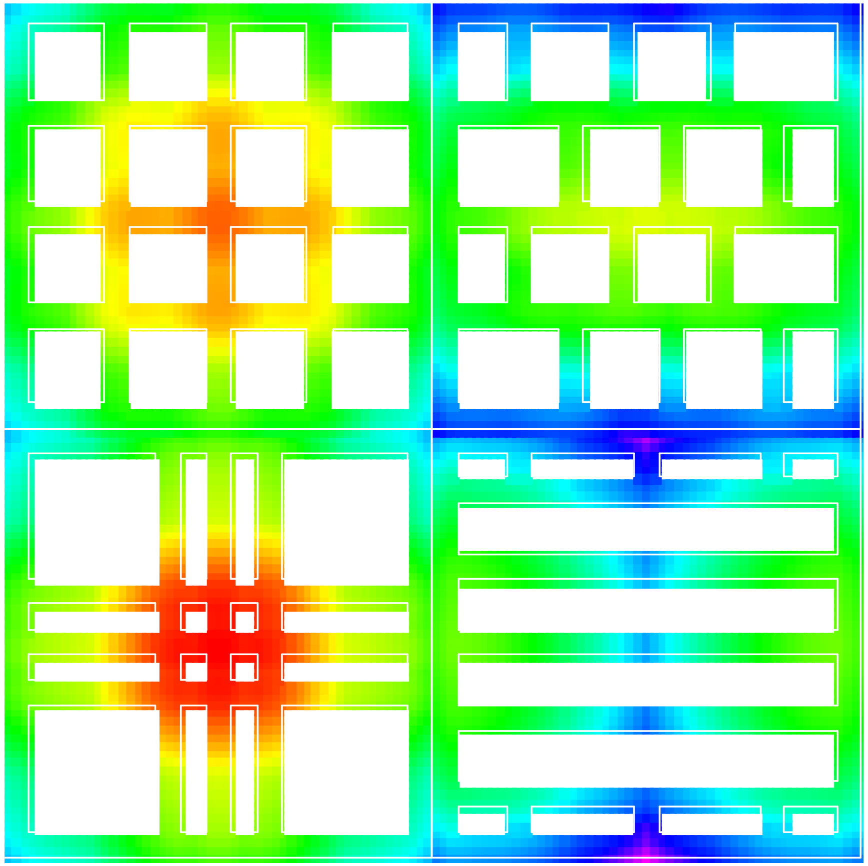
- At a slightly higher scale of around 1500 metres we find Marylebone High Street left above, and on the right at 200 metres we find one of London's unexpected local shopping streets: Lamb's Conduit Street.

- The latter is also marked by a very localised small grid structure, the effect of which is to make the red segment closer to more dwellings. It is very common to find small shopping centres associates with a smaller scaling of the very localised grid, as this reduces distance and creates a kind of localised centrality. At a very localised level we see this metric process again and again. We call it *grid intensification*.

- We find it again left above in Bow Lane, a beautiful shopping alley in the City of London where smaller scale local grid conditions have combined with a strong strategic position off a main thoroughfare to create a local centre. We see the small scale grid also right above in Leadenhall Market, the City of London's most vibrant street market.

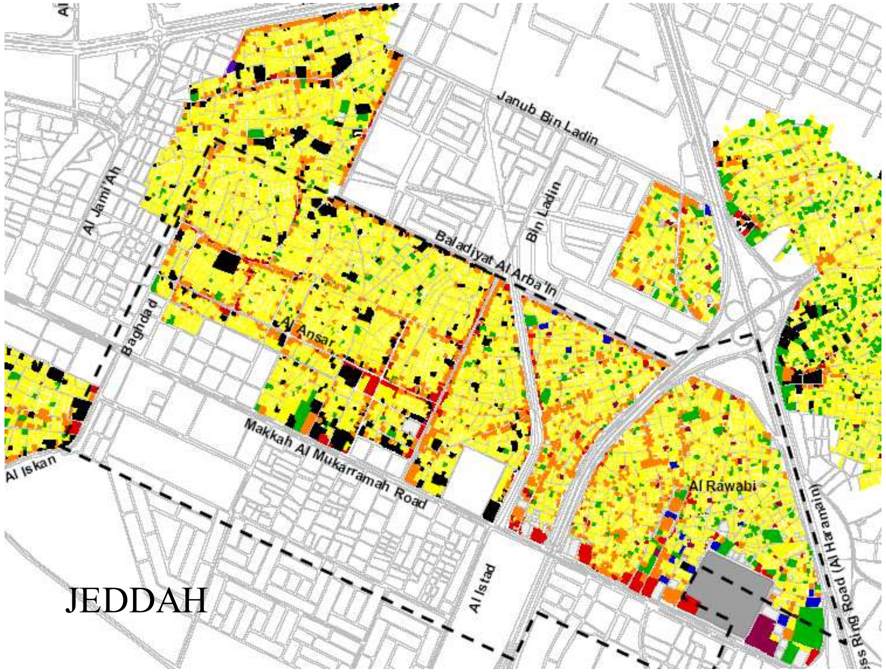
- In all these case the appearance of the centre is the product of strong topo-geometric circumstances at the large scale and a metric intensified grid at the local scale.

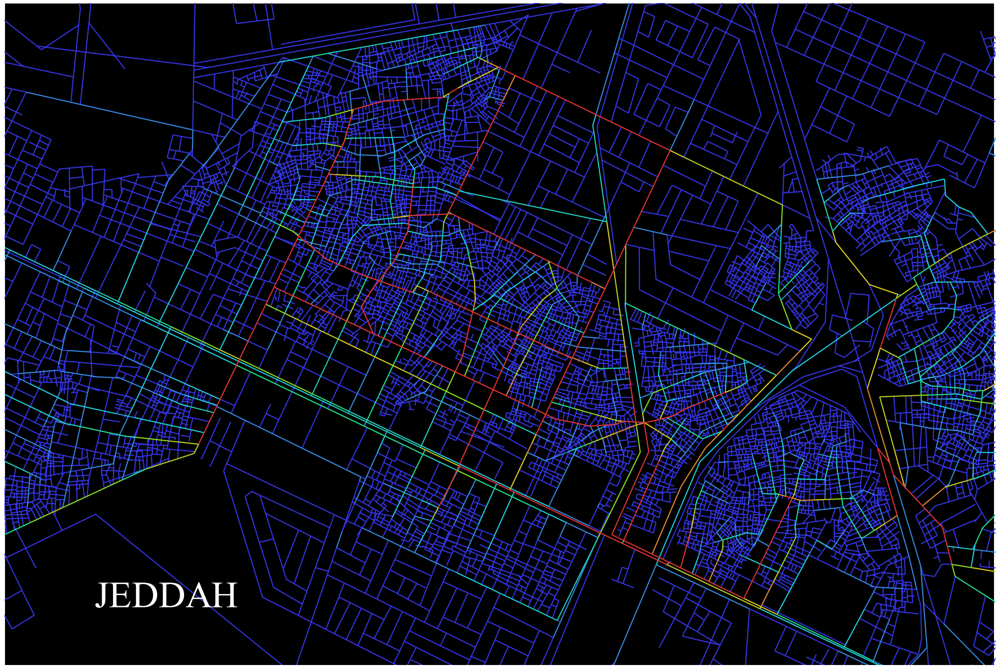
We can see the same kind of combination of global and local grid factors at work in the Edgeware Road, and major alignment from central London to the north west. Along its length are three high streets marked by intensified local grids, separated by sparser grid where there is no live centre activity. Although I am using London examples here, the same kind of phenomena can be found the world over.



- We can demonstrate this local metric grid intensification process theoretically. In the above set of four grids we hold ground coverage of blocks, and therefore total travellable distance in the space, constant, and vary the shape of the grid. Red mean shorter mean trip length to other points through to blue for longer trips. Compared with the regular orthogonal grid top left, interference in linearity on the right increases mean trip length, amd if we elongate the blocks it increases it dramatically

- But more strikingly, if we reduce the size of central blocks and compensate by increasing the size of peripheral blocks, we *reduce* mean trip length compared to the regular grid. This of course is the 'grid intensification' that we often note in looking at centre and sub-centres in cities. Again we find a mathematical law underlying an empirical phenomenon.





- Now let me drive home the point about the link between grid structure, movement and emergent land use patterns, and its dependence on the least angle change rather than shortest path structure, by showing an example of the process in the absence of planning. Above left is one of the unplanned areas of Jeddah with the pattern of small shops and catering outlets marked in red. On the right is the analysis of the through-movement patterns using the least angle measure set at a trip radius of up to 3 kilometres. The correspondence between the two patterns is remarkable.

- In above analysis, we adjust the bounds of the colour spectrum to highlight the difference between spaces. In the following sequence we do not adjust the spectrum in order to compare first the effect of varying the radius of the measure (in effect trip length) and then to compare least angle route selection with the traditional shortest path selection.

Janub Bin Ladin
Bin Ladin
Al Jami'Ah
Baladiyat Al Arba'In
Baghdad
Al Ansar
Makkah Al Mukarramah Road
Al Iskan
Al Istad
Al Rawabi
Ring Road (Al Haramain)

We first set trips at up to 500 metres. The analysis identifies the five main centres of the network of shopping streets.

Raising trip length to up to 1000 metres, we find the centres linked into a continuous network, but focused in the northern parts of the area remote from the main east west route, the Mecca Road


At 3000 metres the main emphasis shifts southwards towards the Mecca Road, but
still identifies the main network.


And at 5000 metres the main focus shifts to a section of the Mecca Road

Now compare the effect of shifting to the traditional 'shortest path' assumption. With a trip length of up to 500 metres, a seeming random selection of street segments is identified, with only the most tenuous relation with the local centres.


At radius 1000 metres identifies a large number of complex local routes, with
little references to the centres andfthe routes connecting them

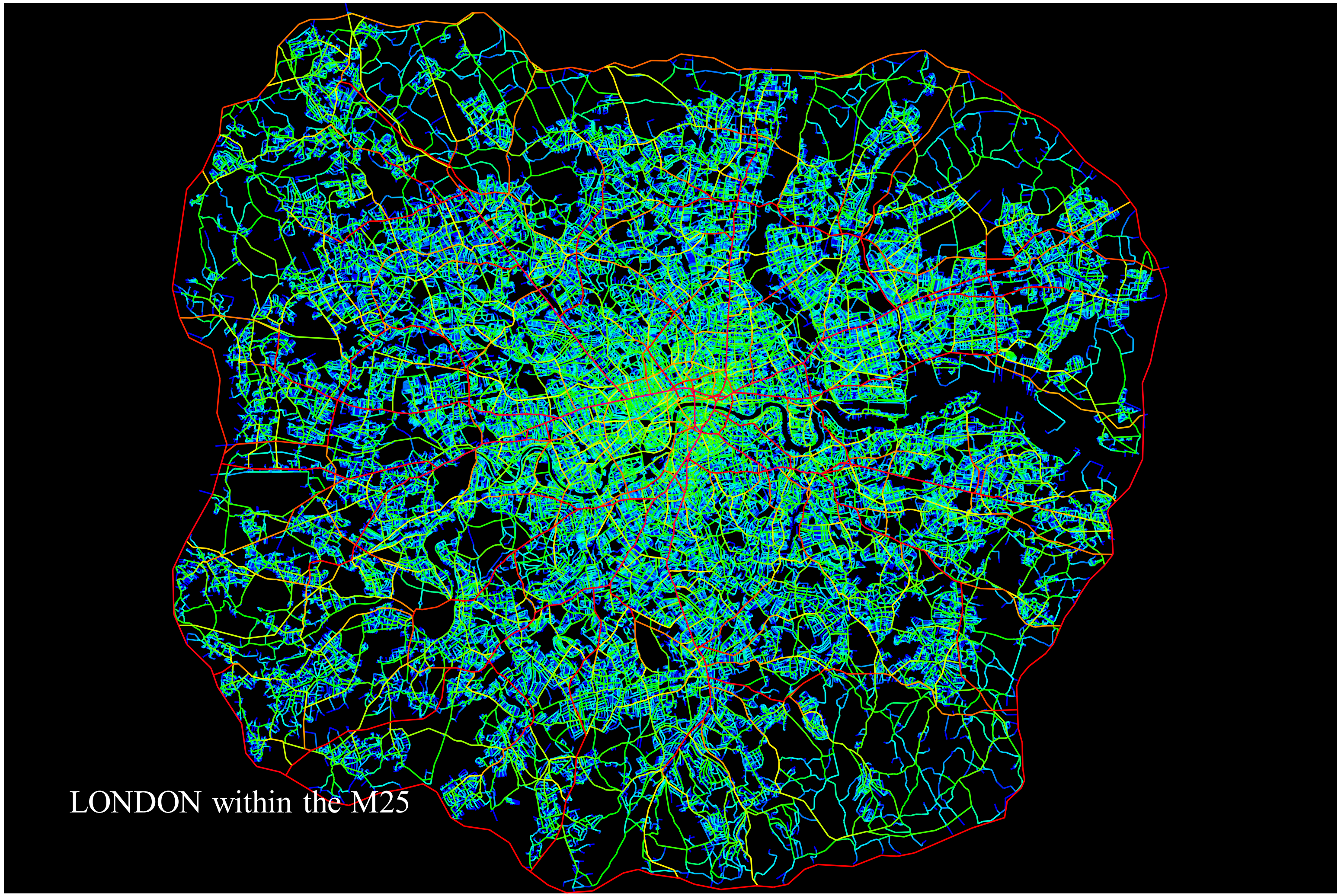

At 3000 metres the focus is increasingly on a small number of highly complex routes
with little reference to the network of linked centres

At 5000 metres only a few of these routes remain, and again there is no reference to the emergent functional structure. These and other results show that traditional shortest path analysis is vrtually irrelevent to the structural and functional dynamics of cities. It is time to give it up.

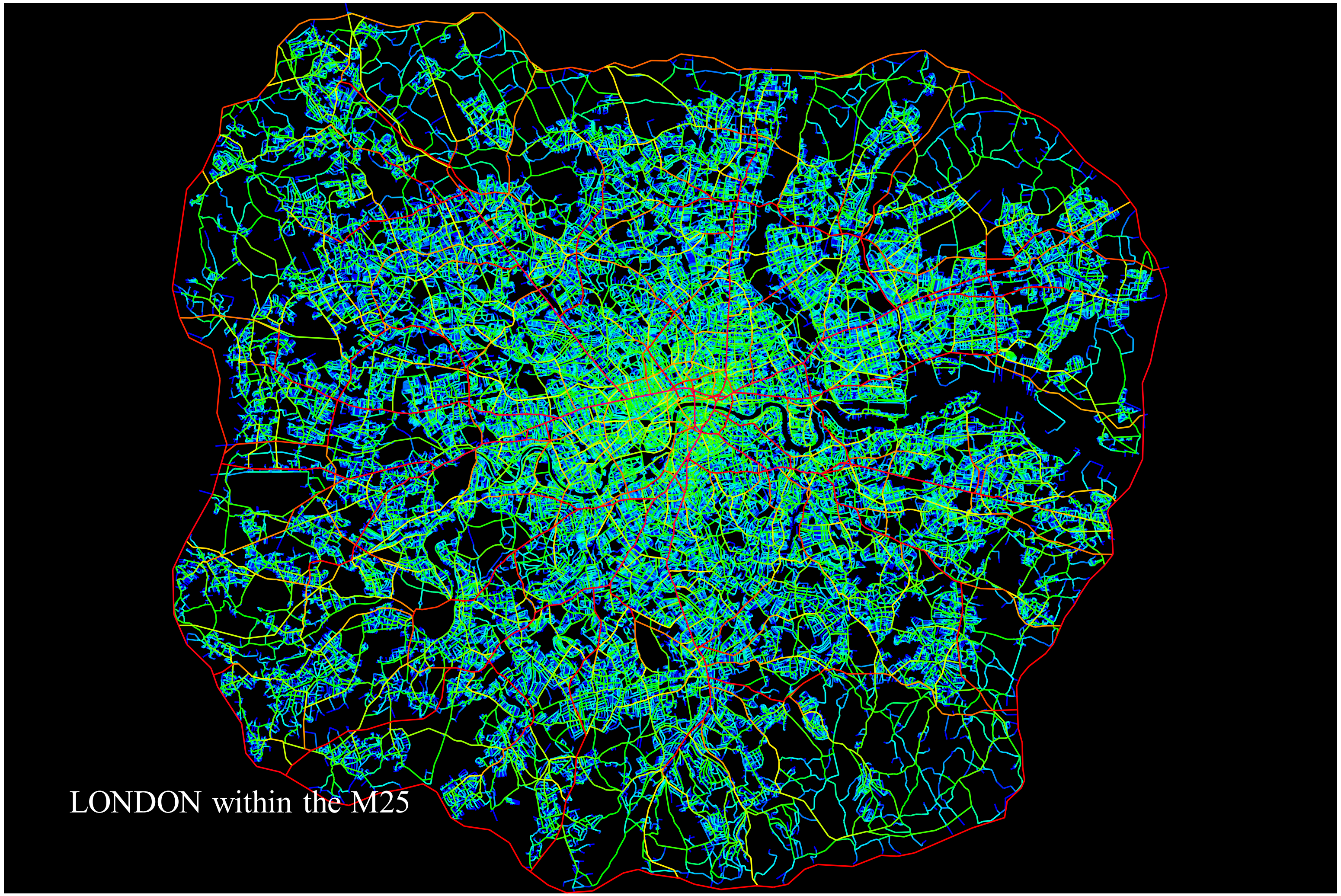
- So how can we theorise this seemingly intricate array of form-function links in the city. We suggest that once the grid-movement relation is understood, everything falls into place. As the urban grid evolves, it creates a pattern of *natural movement*, with some places busier than others due to the structure of the grid. Movement-seeking land uses, such as retail, will then seek out movement-rich locations, while others, such as residence, may avoid them. So a land use patterns begins to take shape reflecting the degree to which activities are sensitive to movement and co-presence.

- As new land uses arrive in the movement-rich locations, they attract more movement, and create *multiplier effects* which then attract more, and more diverse land uses. So in certain parts of the grid, we begin to see *local patches* of mixed, denser activity developing which stand out from the *residential background* as local *centres* and *sub-centres*, sometimes just a few shops and a café or pub, at others much more substantial and more mixed. The scaling of this process is roughly proportionate to the strength of the embedding of the centre in the urban grid, though taking into account also the effect of neighbouring centres.

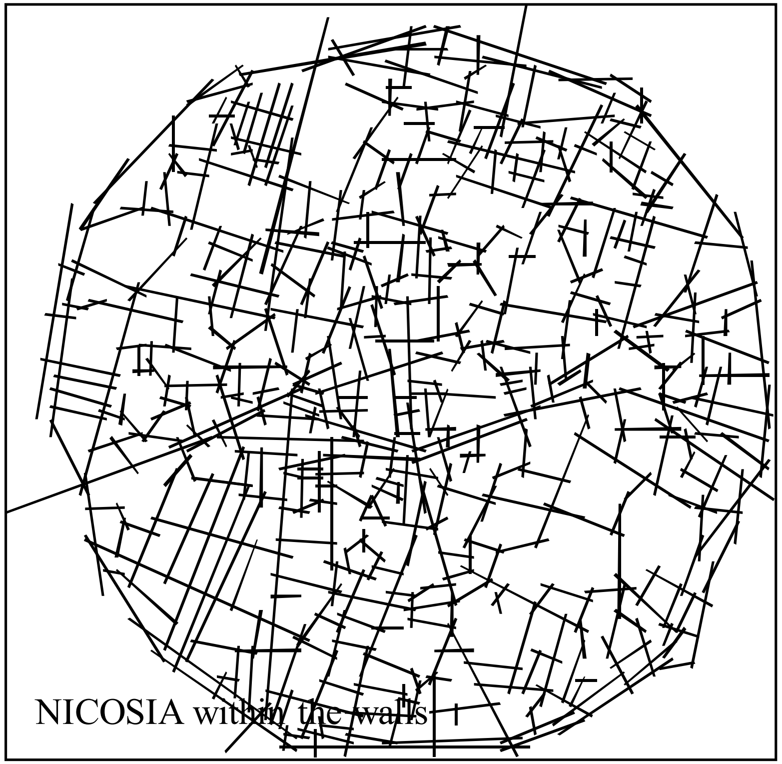
- Where this process becomes intense, it feeds back on to the structure of space and creates *grid intensification* by reducing the size of blocks and making the patch more *inter-accessible* from all points to all other points. So local centres tend to be formed by combined global and local properties: the global to give them reach and co-presence at the larger urban scale, the local to give them the internal inter-accessibility that comes from grid intensification.

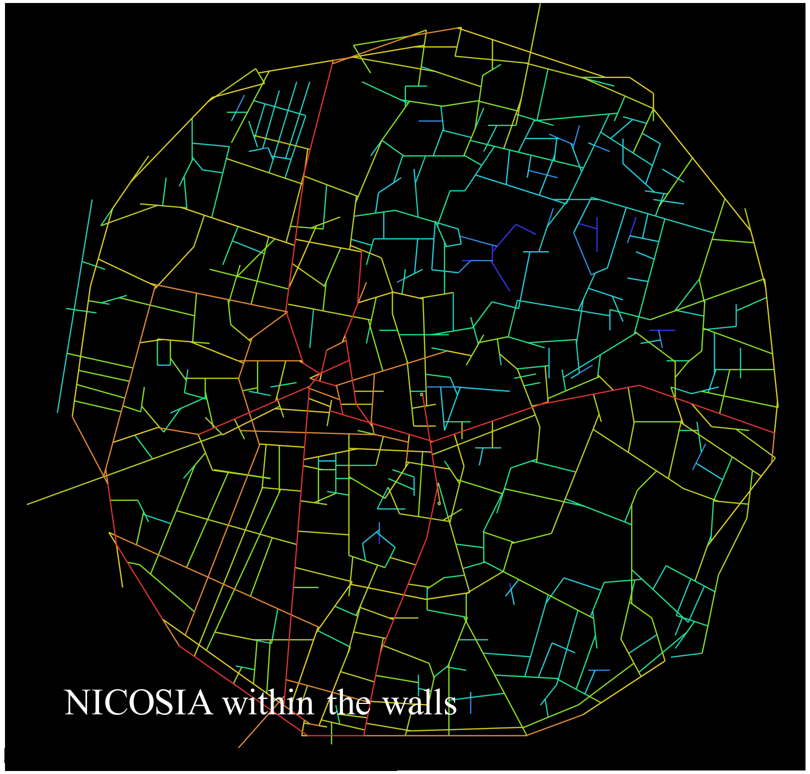


- This series of multiplier and feedback effects, set in train by the grid-movement relation - we sometimes call it the *city-creating process* - is the process through which the city acquires its universal form as a *foreground network of centres and sub-centres at all scales set into a background network of residential space*. This is the space syntax definition of a city. Through its impact on movement, the network has set in train a *self-organizing* process by which collections of buildings become living cities. In terms of how we should model cities, *network configuration* has shaped the pattern of differential *attraction*, that characterizes all cities. *So configuration*, not *attraction*, is primary. This is how cities become seamless networks of busy and quiet places, often in very close proximity, and it is probably this more than any other urban phenomenon which renders cities so livable.



So we have found our *dual* structure, and we can explain it. The *foreground* structure, the network of linked centres, has emerged to maximise grid-induced movement, driven by micro-economic activity. Micro-economic activity takes a universal spatial form and this type of *foreground* pattern is a near-universal in self-organised cities. The residential background network is configured to restrain and structure movement in the image of an particular culture, and so tends to be culturally idiosyncratic, often expressed through a different geometry which makes the city as a whole look spatially different. We call the first the *generative* use of space since it aims to generate co-presence and make new things happen, and the second *conservative* since it aims to use space to reinforce existing features of society. In effect, the dual structure has arisen through different effects of the same laws governing the emergence of grid structure and its functional effects. In the foreground space is more random, in the background more rule-governed, so with more *conceptual intervention*.





- We can illustrate this *dual process* most clearly in a city with more than one culture (now unfortunately separated): Nicosia. Top right is the Turkish quarter, 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. 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. This because micro-economic activity spatializes itself in a universal way to maximise movement and co-presence, while residence tends to be an idiosyncractic spatialised culture whose expression is primarily geometrical. Since residence is most of what cities are, geometrical difference in cities tend to be highlighted.

- So we have seen a substantial component of the syntax theory of the city – the component we may call the *consequences* of the grid structure. We have seen that the grid generates movement, and this then shapes the pattern of movement-sensitive land uses, and this, with feedback and multiplier effect leads to the underlying *dual* form of the city as *network of linked centres at all scales set into a background of residential space*. Within this framework, of course, we would also expect that the scaling and distancing of centres will be affected by other centres, but this is clearly secondary to the grid process.

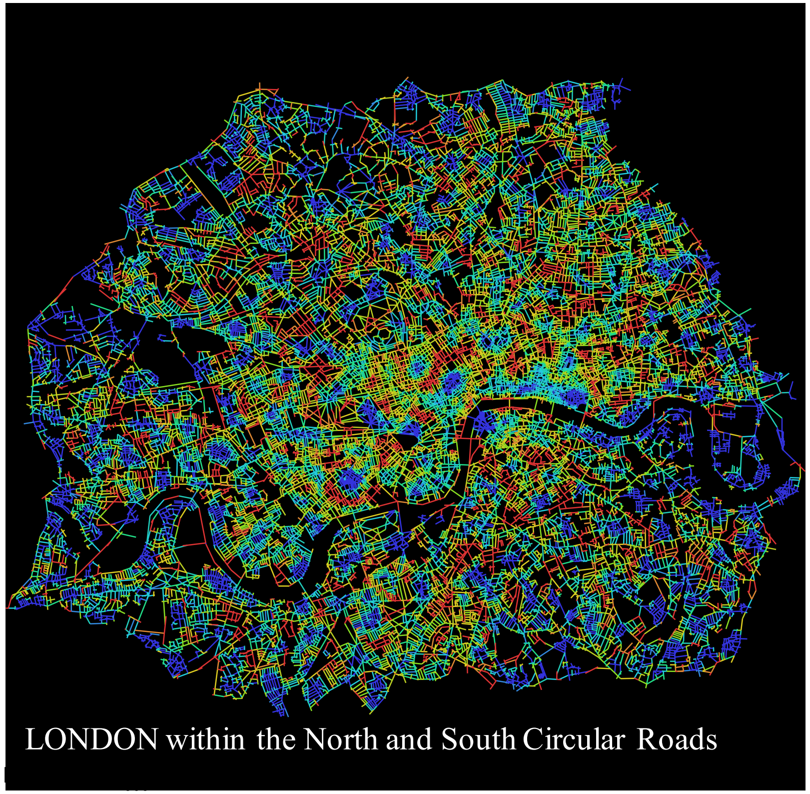
- The critical process on which this depends, the lawful effect of the grid on movement, is in effect *masked* by the *assumptions* of the urban model paradigm:

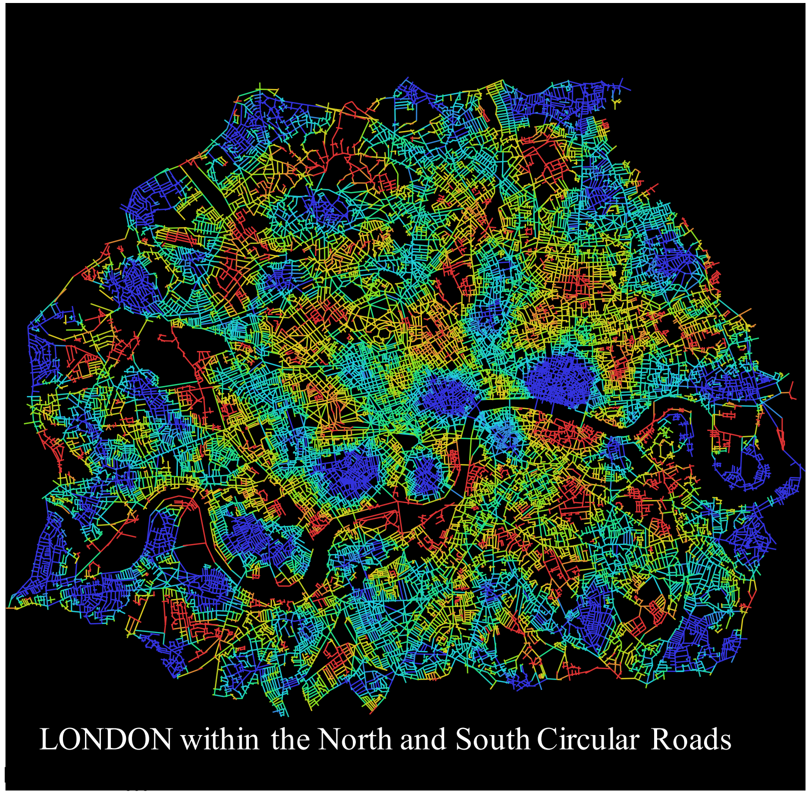
- - traditional urban models assume that attraction is the primary force causing movement – syntax models show it is a derivative force

- - traditional models assume that attraction itself is in the first instance an independent variable – syntax shows, it is a dependent variable of the grid structure

- - traditional models assume that the fundamental mechanism is inter-zonal flows – syntax shows it is the impact of the grid structure on random flows that is fundamental

- - traditional models assume that the field in which the system operates is metric – we have seen that it is in general topo-geometric and only locally metric.



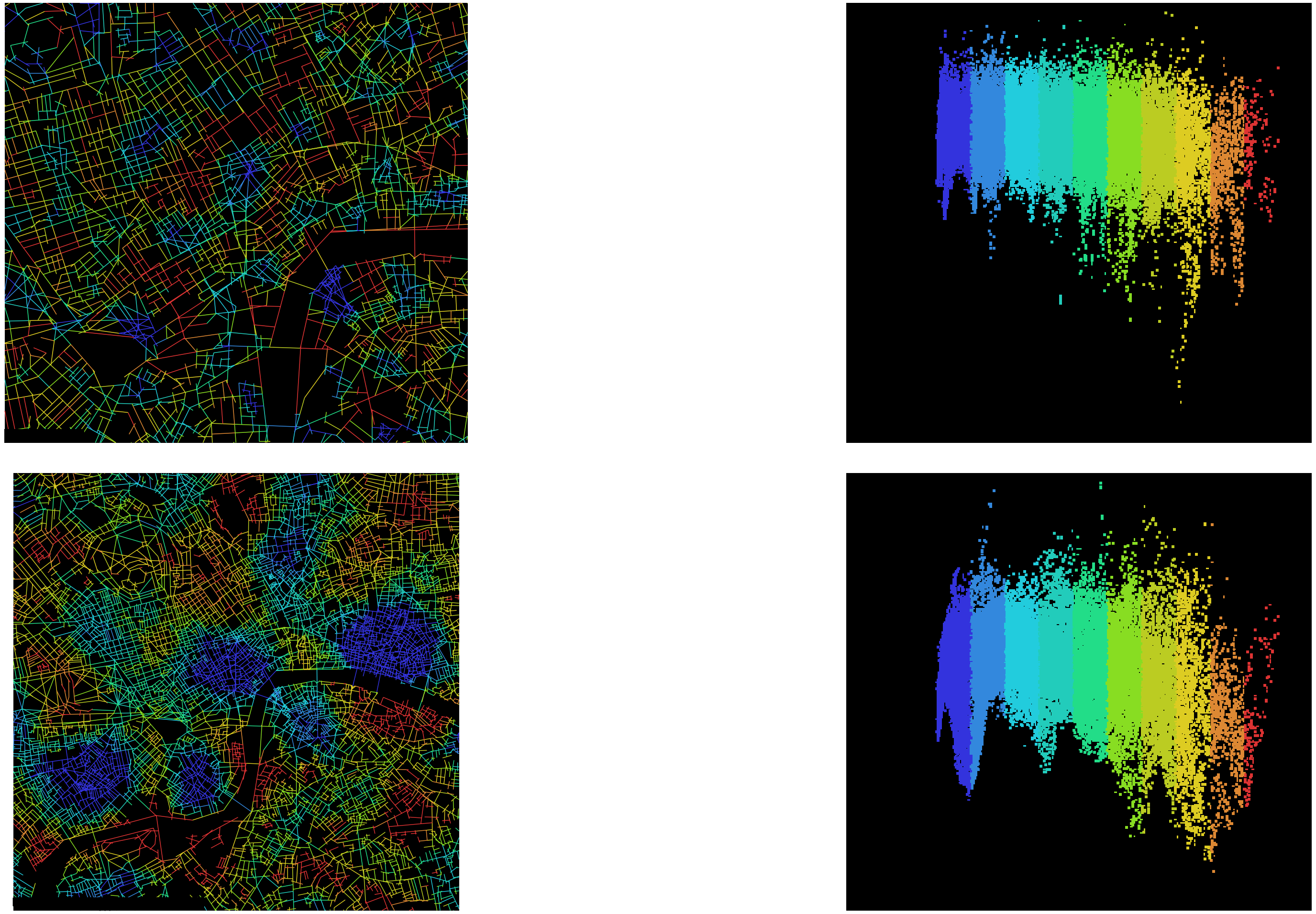


- But what about the local metric structure. In fact we have recent found a way to show both the essentially metric structure of the local patchwork of areas, and at the same time to show that there is after all a natural spatial *area-isation* of the city.

- If we calculate mean distance from each segment to all others within a certain radius, we do not find the kinds of line structures that other measures have identified. We find that at each radius a *patchwork* of areas is identified, and as we increase the radius the patches grow larger. I do not have time to show details here, but we now have a body of formal work which shows that what we are finding here is the natural discontinuities in the urban network brought about by the placing and shaping of urban blocks and other impedances to the grid. We call it the *partitioning structure* of the grid.

- We can be sure that this patchwork is a *partitioning structure* at each radius by showing that at each radius the measure of the metric distance of all points to all others can be closely emulated by another. Left above is the patchwork identified in London by mean metric distance from all segments to all others within a radius of about .5 of a kilometre. On the right is the effect of measuring the rate of change in the segment count from each segment between radii above and below the radius, so that the band is same same width as the radius – so in fact the rate of change for 750/250 metres. Both measures are picking our the *discontinuities* in the network which spatially differentiate the areas from each other. By looking at the patches you can begin to see the discontinuities and the spatial differences between areas that make up the area differences.

- We are still in the early stage of trying to find a formal method for testing these patchworks against functional differentiation, but this particular patchwork for central London is remarkably suggestive. In particular, many *live centre* areas with strong retail and catering are picked out as blue patches in a context of yellow and red residential areas.



We can then use scattergrams to picture the shapes of space in the patchwork, with mean metric distance at the global level on the horizontal axis, and radius .5km on the vertical axis in the top row and 1.5km in the bottom row. The blue patches, which are metrically integrated zone show as the *stalactites*, and these become broader with increasing radius and at higher radii yield a large scale regional picture of the city.

- These results suggest not that there are, spatially speaking, natural areas in cities, but something more interesting and perhaps more lifelike: that at each scale there is a *natural area-isation* of the city into a patchwork of spatially distinguishable zones. This is after all how we talk about cities. We do not mentally regionalise them at one level only.

- But they do demonstrate that the area structure of the city is again a *dependent variable of the grid*, and it must be among the objects of a theoretical model of the city to identify these. Our final critique of traditional urban models is then that by defining area structures at the outset, and arbitrary ones at that, they are rendering invisible any tendency for the city to form natural areas and the functional differentiation that this seems to bring with it.

- So I am not criticising the practical usefulness of normal urban models. They do many things which syntactic models cannot (yet !) do, and play a well established role in critical aspects of the planning process – though they do also have the downside of bringing a prestigious and poorly understood numerical technique into the planning process that is actually insensitive to the critical form-function dynamics of the urban system.

- Syntactic models on the other hand are transparent, simple to build, and capture *in the very structure of the model* those critical dimensions of structure and functional dynamics. I suggest then that they are the proper basis for theoretical models of the city. So let me end my argument by trying to give space syntax some scientific and philosophical credentials.

- We have already noted the Newtonian foundations of urban models in the gravity equation and its associated conceptual apparatus. But there are other senses in which urban models are not Newtonian at all, and in fact syntax models make a more fundamental Newtonian point. The most important single idea in Newton, anticipated by Galileo, is the *principle of inertia* – that bodies can be assumed to be moving in a straight line forever until something forces them to deviate from this line. The implication is that movement does not need to be caused. It was this idea that more than any other broke the mould of the Aristotelian system and opened the way for Newton's geometrical description of the universe.

- The theory of *natural movement* emulates this, in that we do not need to concern ourselves with the causes of movement, since all we are saying is that given that people move from all places to all others, then this will be the impact of the space network on the emergent patterns of flows. The theory of *natural movement* outlined here is, I suggest, a kind of *inertial* theory of movement. Given that people are moving from everywhere to everywhere else, a pattern of flows will emerge due to the geometric and topological structure of the urban grid. This seems thoroughly Newtonian.

- The second point has to do with how we should see space from the point of view of theories of space in science and philosophy. I am saying this because our theory clearly violates current paradigms of space in the social sciences. These explicitly deny space *existence*, *invariance*, *autonomy* and *agency*, seeing it only as something amorphous until given the imprint of human or social action. Social science theories are for the most part theories of the *spatiality* of economic and social processes, but do not address *space itself* in the architectural sense.

- So we must look elsewhere for respectability. Let me remind you of the revolution in the concept of space that came with the theory of relativity. In Einstein's theory space is everywhere invariant until given structure – distorted we might say – by the presence of bodies with mass. But from then on it is space not the bodies which have agency. Gravity for example is the curvature of space time induced by bodies, not properties of the bodies themselves. So with Einstein also space has *existence*, *invariance*, *autonomy* and *agency*

- In a sense, we are also emulating this, at least at a conceptual level. Human space is everywhere invariant until it acquires structure by virtue of the presence of physical objects such as buildings. The presence of physical object in space creates structure, and it is this structure that sets in train the city creating process. So space again has agency. I do not want to press the idea too far - only to show that the spatial paradigm we have proposed does not seem to be entirely foolish from a scientific and philosophical point of view, even though it is wildly disconsonant with current social science notions.

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