University of Pittsburgh GSPIA **Confronting Vulnerability and Violence in the Urban Century, November 14-15, 2016**

casa UCL University College London

Complexity and Resilience in Cities

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Preamble

Complexity and Cities

Paradigms for 21st Century Cities: Complex Adaptive Systems, Big Cities and City States, Smart Cities, …., amongst others

Cities as Interactions

The Network Paradigm: Vulnerability Articulated as a Fracturing of Networks. Resilience as Networks Hard to Fracture

Some Examples from Large Cities and Systems of Cities

Short Term Transport Disruptions, Long Term Climate Change Flooding, Medium Term Infrastructure Projects, Regional and National Breakdown

Conclusions: Generalising These Ideas

How Relevant Is All this to the Global South – A Note on Our Work in Sao Paolo, Senegal etc.

Preamble

Let me begin with a set of working assumptions:

- Jane Jacobs in 1961 said that cities are places where people come together – realms of social interaction – ***networks*** are the glue that keeps them functioning
- Whether they function well or poorly depends on the '***what is glued to what***' in the context of the purpose for which we come together
- In general cities are really a product of the last 200 years with an upper limit 1 million people until the industrial revolution. Now there is no real upper bound –by 2100 all the world will be cities of one form or another; we will all be urbanised, all glued together ! And this is due to technology and continually developing new technologies.
- As they grow and evolve, cities are becoming more complex – more diverse as new layers of technology are added to old and as our ability to interact increases globally
- In short more things are getting glued together. The challenge here is to explore ***what happens when things get unstuck, unglued***, when the glue melts or is destroyed or when ***the glue is of the wrong type*** or when there is ***no glue in the first place***.

Complexity and Cities

- Our view of cities is changing very rapidly at the present time. In the last 30 years, a new paradigm coming from the sciences but also being heavily influenced by other domains argues that we build human systems – economies, societies, organisations – cities of course – indeed our households from the ***bottom-up***.

- In short , the systems we develop are evolved – ***they are more like organisms than machines***; they are adaptive, they respond to positive feedback in that they innovate, they are largely products of millions of decisions all fashioned from the bottom up although sometimes they are articulated as if they were from the top down.

- There is no grand plan for such systems and in theory they are largely unpredictable. Such systems adapt and in this sense they are resilient; they adapt to changed circumstances. They may collapse of course but this is rare and even collapse is a kind of adaptation. James Lovelock's ***Gaia*** hypothesis of the earth as a self-sustaining system but not necessarily a desirable one from our point of view, says it all

- The Santa Fe Institute group refer to these kinds of systems as complex adaptive systems (CAS). Their hallmark is as John Holland in his book *Hidden Order: How Adaptation Builds Complexity* says is that these are systems that ***have coherence under change***

- Essentially these are systems that get increasingly complex as they evolve: this question of increasing complexity is key I think to thinking about any kind of systems where we interact with one another socially or through nature; in short they are generic to the human condition.

- Networks provide a good model of these kinds of system because they show us what relates to what and who relates to who and are useful in thinking about questions of what are the best ways of relating and what happens when relationships break down. Of course I must stress that this is just one perspective amongst many.

- One key point is that even though the system may be resilient and in the Gaia sense sustainable, this does not mean the system is best in any sense; some of the biggest problems in human systems are those that are caught in the trap of being sustainable, resilient and in fact invulnerable but at the same time extremely undesirable

- I want to introduce albeit briefly two more conceptions of the 21st century city as they come up time and again in discussions of complexity, resilience and sustainability: the idea of the **City State**, and the idea of the **Smart City**

- In the last 30 years, our view of big cities has radically changed. Big is now beautiful, big cities are diverse, appear to have more opportunities for everything and everybody, they have buzz, despite the very evident downsides such as increased crime, poverty and so on. But the buzz outweighs the poverty.

- So the idea of the city state rather than the nation state has come onto the agenda as the appropriate domain for action. There are profound implications for dealing with resilience and vulnerability at the city level or at the level of the nation state that complexity theory does have something to say about. I will park this here and introduce the second conception, that of the Smart City

- The smart city is the most recent wave of computerization in society in my view – it is IT spreading out into public places but it is also tied up with continuing massive extensions of the way we interact and in this sense, the city is again a good focus.

- In this sense the **Smart City** is something of a buzz word but it does enable greater interaction and if we think of cities as linking people using good glue – good communications, increased interactions from smart technologies would appear to be good thing. But equally well it can divide

- Complexity, the City State and Smart Cities all introduce ideas about how we can think of modern cities consisting of parts and their populations as interacting for some purpose

- The big question is are these ideas useful everywhere ? – for cities in the developed, developing and underdeveloped world, for cities of the Global South as well as the Global North, for the Asian Tigers as much as the cities of the Middle East, of war zones as well as relatively peaceful enclaves?

- I will now move onto cities as sets of interactions – cities as elements, activities, individuals, populations whose functions depend on interactions, on networks which if fractured or broken cease to function. This enables us to define resilience more directly and to contrast this with fragility and vulnerability.

Cities as Interactions

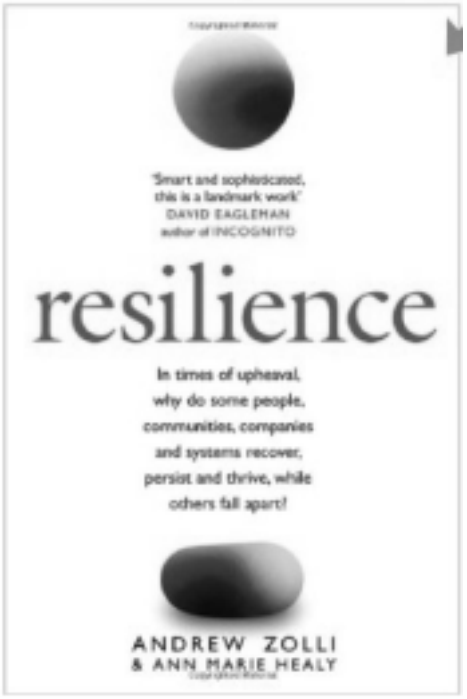
- Imagine a network which is disrupted with some of its links being broken. In a worst case scenario, no communication can take place between one part and another part and in the less worst case, the disruption leads to much increased costs of communication using less direct links

- Networks and their robustness to fracture is thus of the essence. As a network adds more and more redundant links, that is it is harder and harder to disrupt it for if some links breakdown, others kick in. In fact it would appear that more and more of our systems are prone to disruption because we insist on building systems with not enough redundancy so that costs are minimised.

- This is why older networks can be more resilient because they were often overdesigned.

- Now in the popular science book ***Resilience*** written by Zolli and Healy in 2012, the reviewer in ***Time Magazine*** had this to say of the ideas:

*"In the 21st century, disruption is going to become the **new normal** in ways that we can't even predict. All we can do is learn to bounce back better …"*



- In fact we now have quite a lot of science to help us in thinking this way and much of this grows out of the systems approach, its successor complexity theory, and of course its specific tools such as network science.
- A science of resilient systems is in the making depending on new notions about systems as much as developments like big data.
- It depends on notions such as how can networks remain robust while at the same time being fragile, how can they suddenly disrupt without any obvious slow and sure warnings, what bits of them can be attacked with little or nothing happening and what bits can be attacked with a lot happening.

- This is the science of small worlds, tipping points, weak ties, key hubs, catastrophes, bifurcations, order effects, infinite repercussions and so on. It is the science of phase transition, of complexity and most of all of redundancy in systems. It is the science of heart attacks, and societal collapse and much else besides. It is the science of how the flows and interactions, how social networks keep the city functioning.
- There are many many examples particularly pertaining to transport but peel back the layers and the same logics apply to everything from the financial crisis to the spread of epidemics.
- My recent favourite example is the M25 orbital road around London – in effect our beltway – which has not had one day free of closure in the last 3 years.
- Another excellent example of all of this is the forest fire and let me tell you how such a fire works. Imagine a grid of trees widely spaced – a tree catches fire due to a lightening strike but burns out. As the trees get closer together, those adjacent to one another burn but only when 59% of the area of the forest is full of trees, does the entire forest burn down. This is the percolation limit – absolutely critical for breakdown.
- This is a great example of the **resilience conundrum** – the forest is resilient to fire if the trees are widely spaced but fire is necessary for renewal of the forest with young trees

Some Examples from Large Cities and Systems of Cities

Short Term: disruption on the London tube: an example of how big data can help in coping with disruption

Long Term: flooding in the London region due to rising sea levels in the North Sea – 1 metre over the next 100 years

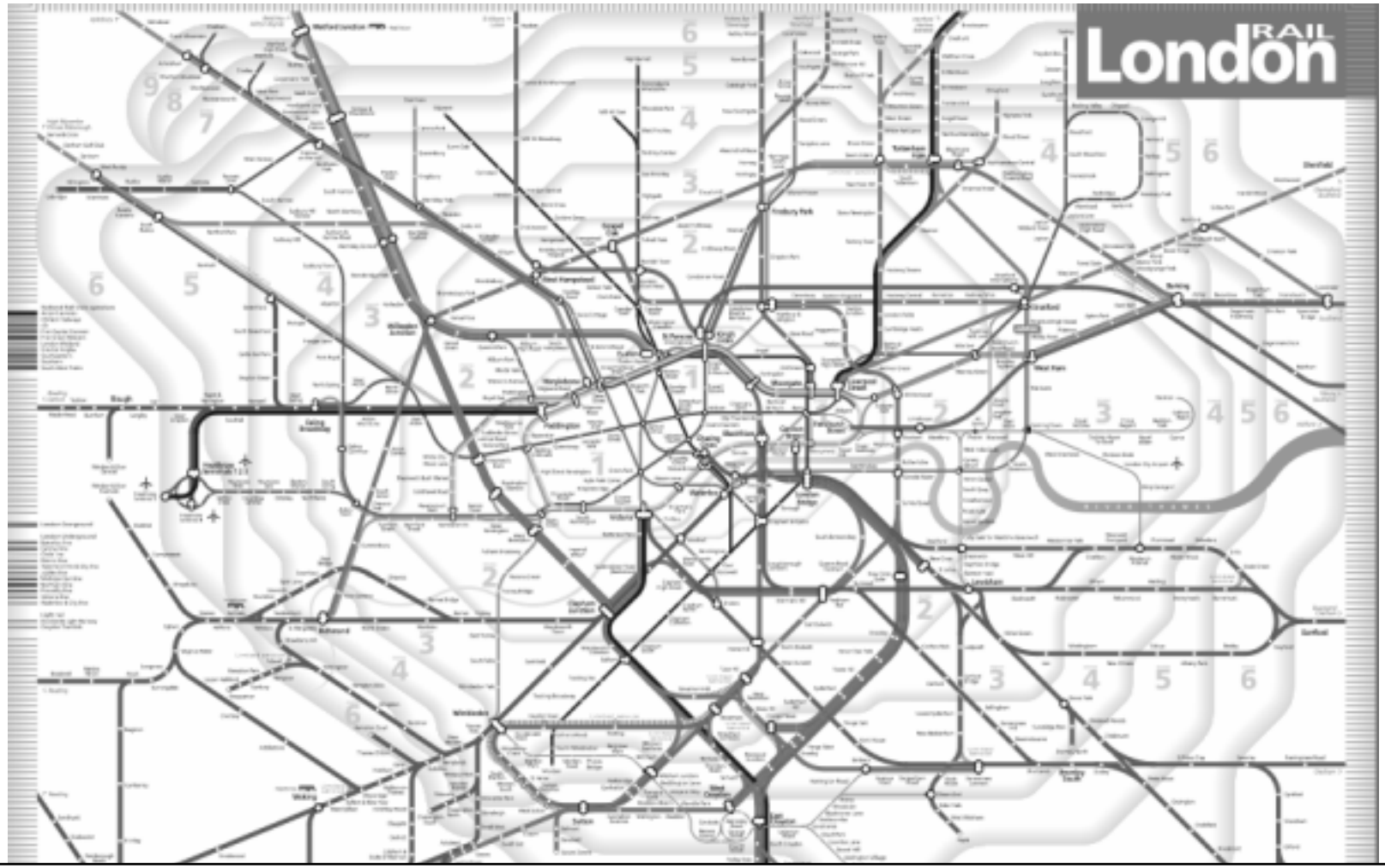
Medium Term: new transport infrastructure projects with large scale regional repercussions

Very Long Term with Very Short Term Consequences: political upheaval and fracturing of the consensus.

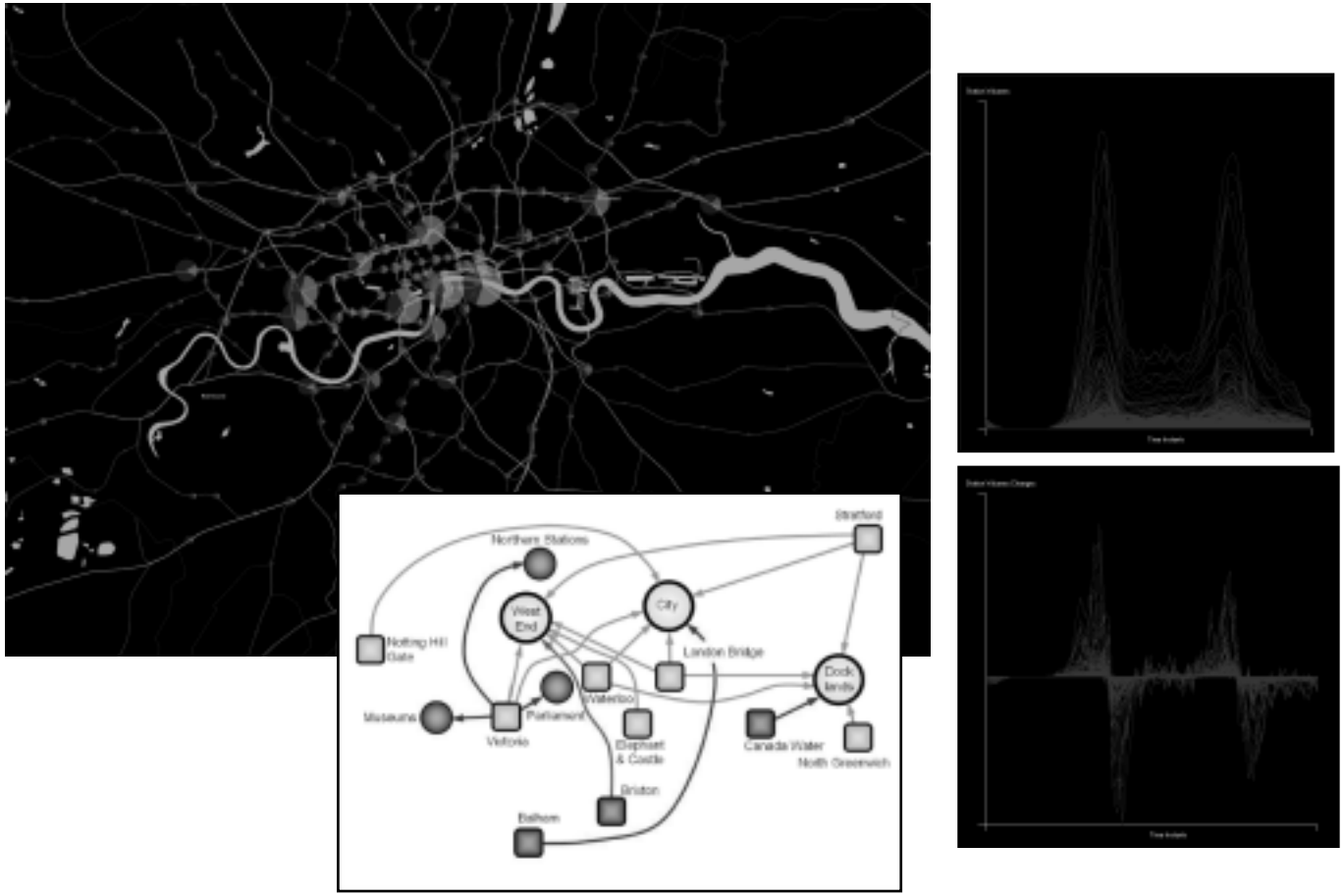
Each of these examples articulate the problem as a network – some quite literally with networks explicitly carrying the phenomena of interest, some much more implicit with respect to the way the processes play out.

Short Term: Disruption on the London Tube

- For all public transit in London, we have real time sensed data from the smart cards – Oyster card – which involves all tap in and tap outs by unique ID number with location and time for every person over a 3 month period in 2012: covers the impact of the Olympic Games which is why TfL gave it us
- 12 million a day, 75 million a week, 300 million a month, nearly 1 billion for every half year. This is very big data – simply to explore it takes a lot of computer time. It is very good data in that we can begin to get a very detailed sense of how people travel over time – the routiness of travel but there are a lot of holes in the data too.
- We are able to examine disruption either hypothetical and real – we will look at the tube and then the bus; the impact of closing stations, a signal failure and a bus strike

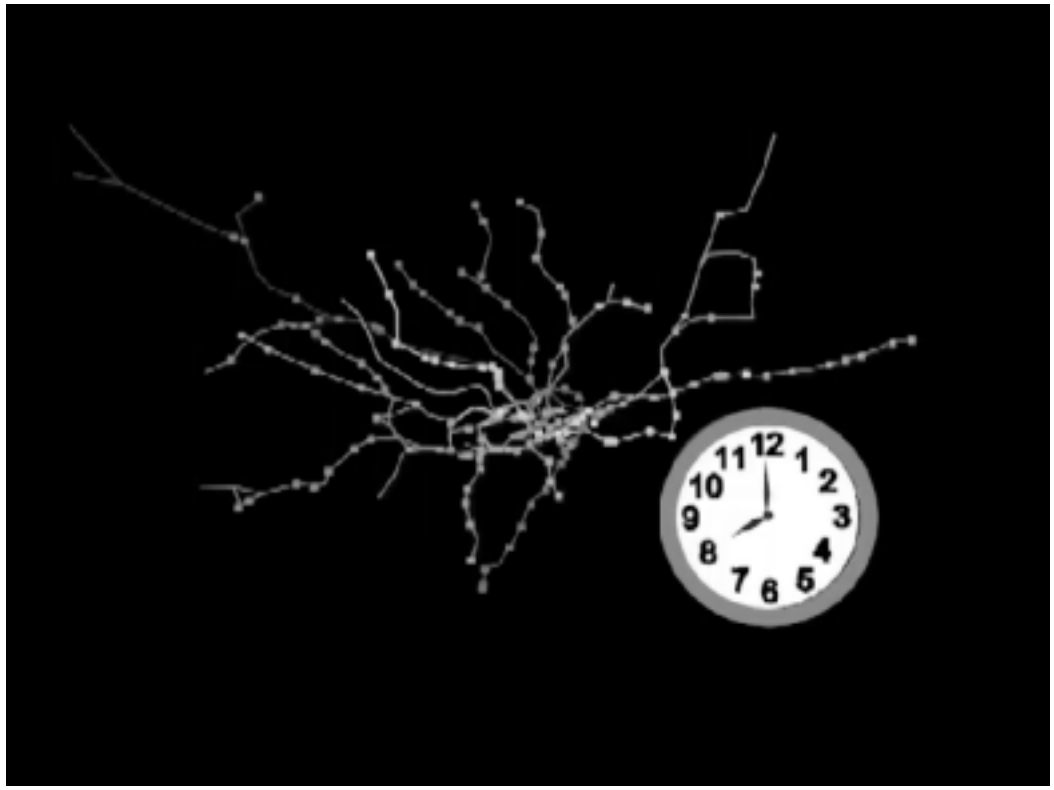


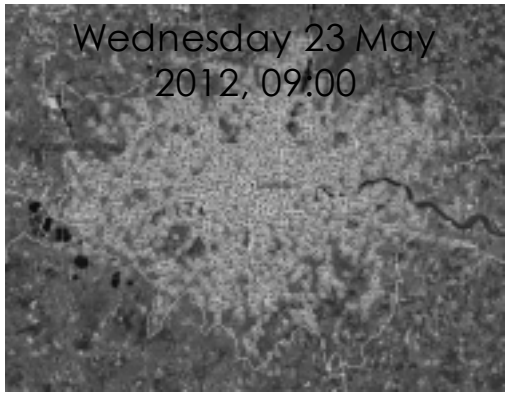
Tube, Overground and National Rail Networks in London
where Oyster cards can be used



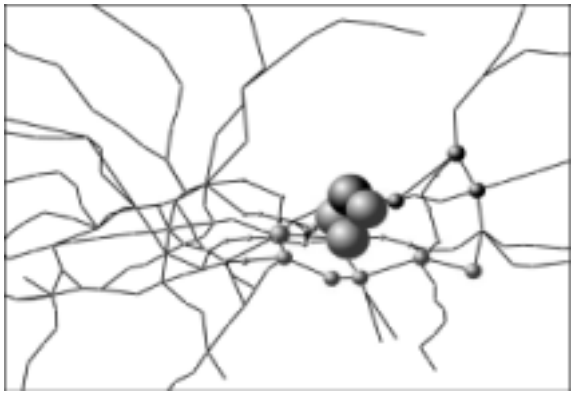
Roth C., Kang S. M., Batty, M., and Barthelemy, M. (2011) Structure of Urban Movements: Polycentric Activity and Entangled Hierarchical Flows. **PLoS ONE 6(1)**: e15923. doi:10.1371/journal.pone.0015923

Animation over 24 hours of speeded up position/time of tubes: How can we match this supply of vehicles from the API queries to the demand from the Oyster card data?

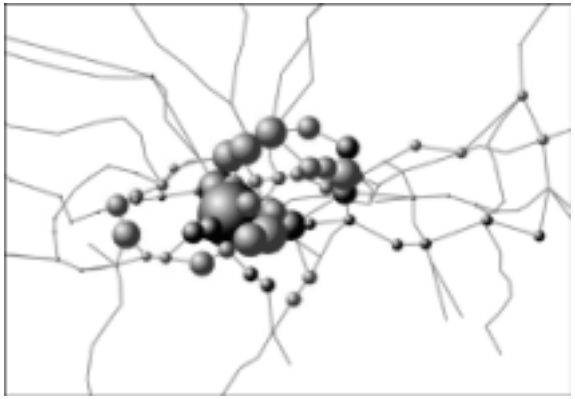


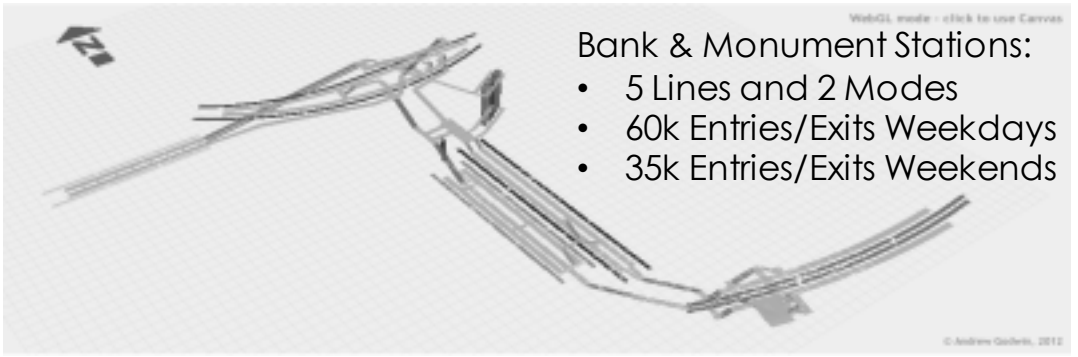


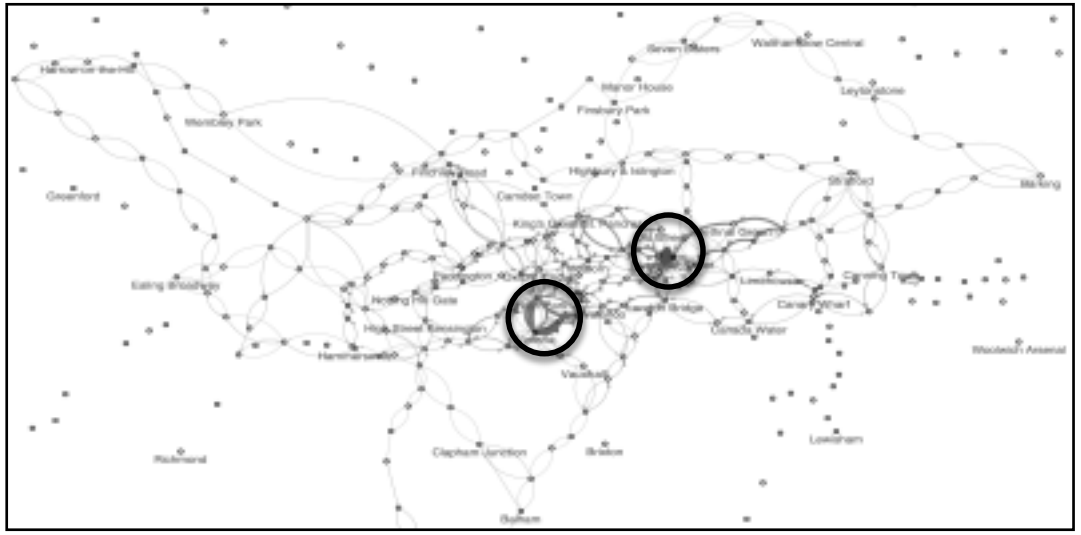
Disruption caused by closing Liverpool Street in terms of the graph of the tube network



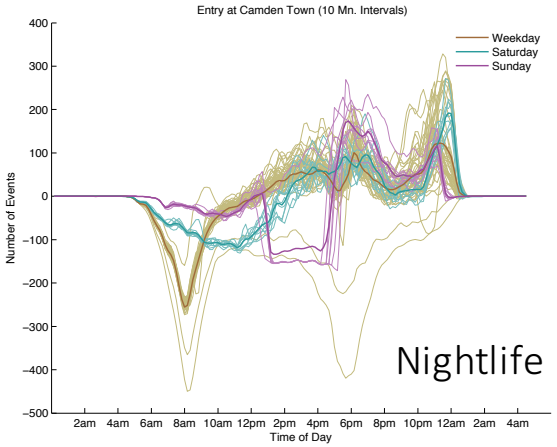
Closing Green Park – shifts in betweenness centrality

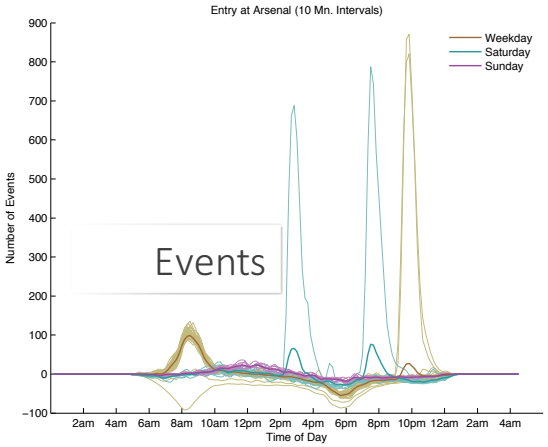


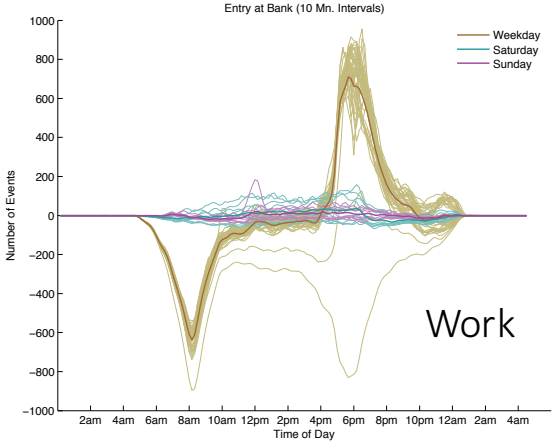


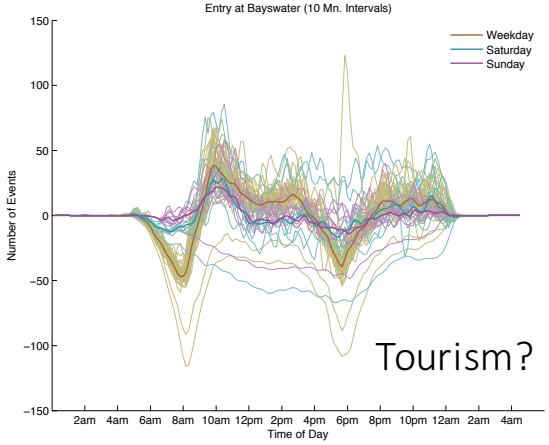


Particular Events: Weekdays, Saturdays and Sundays



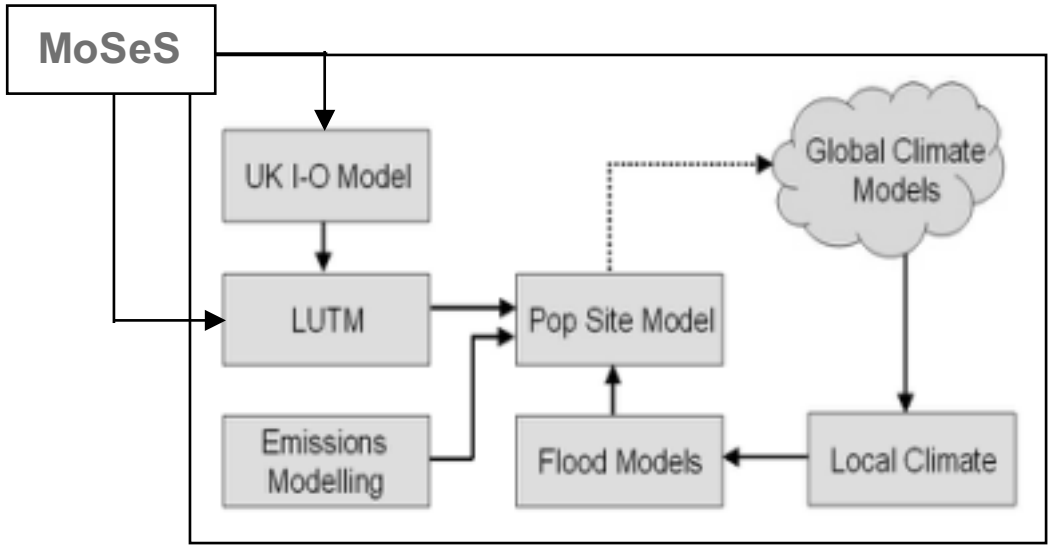




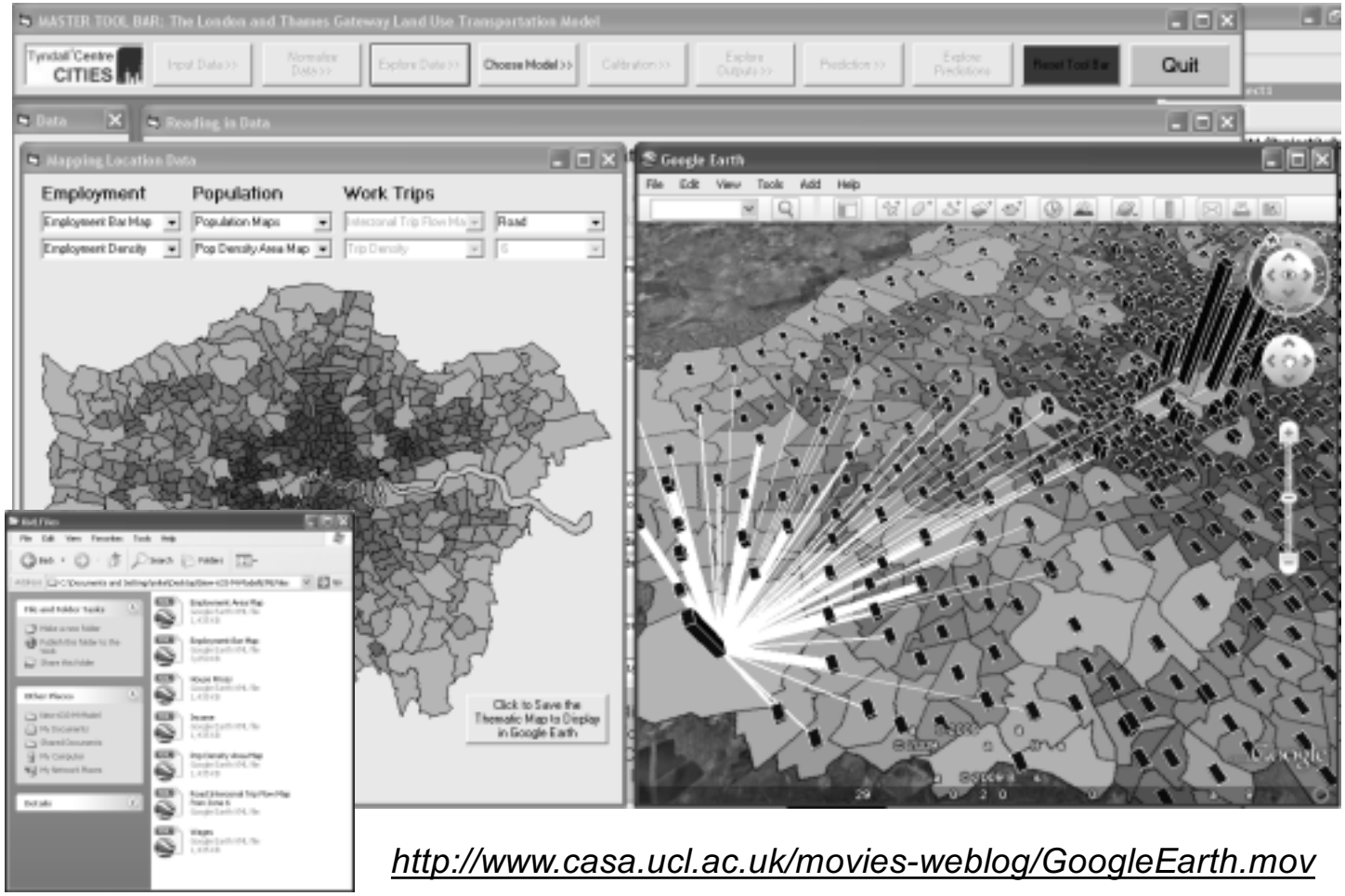


Long Term: flooding in the London region due to rising sea levels in the North Sea – 1 metre over the next 100 years

We have been involved in a large consortium project led by Newcastle Civ Eng to look at an integrated assessment of climate change in Greater London

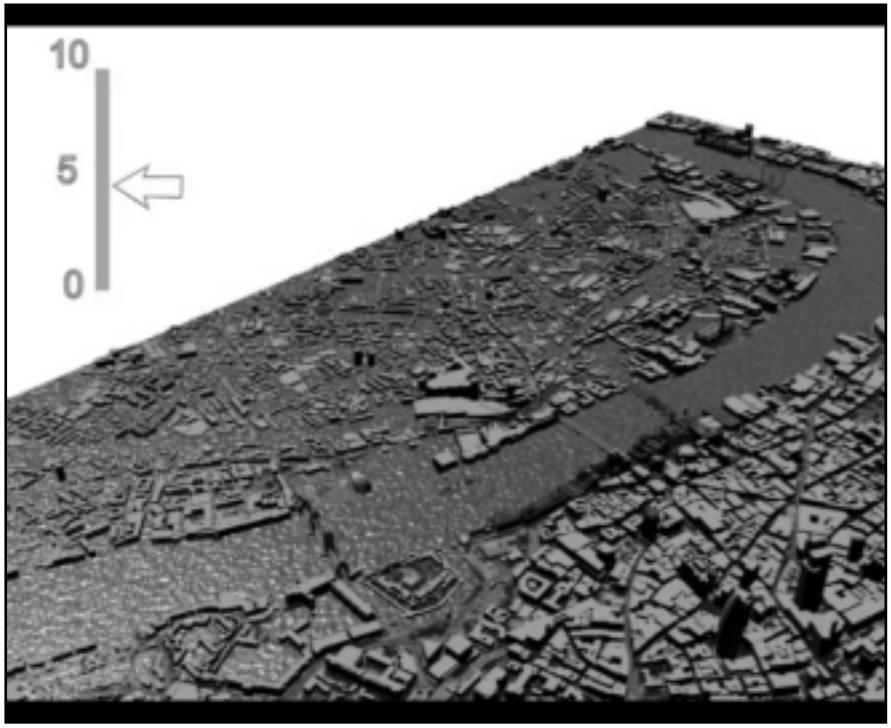


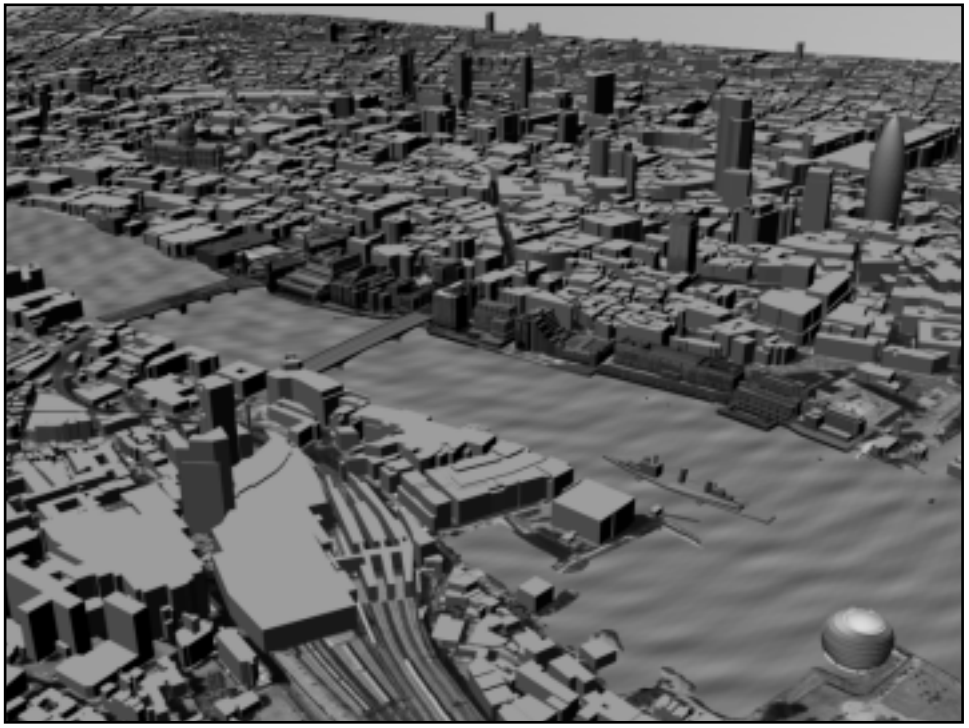

HOW LONDON COULD BE AFFECTED BY FLOODING FROM THE SEA WITHOUT THE THAMES BARRIER
Tower Bridge
Isle Of
Millwall Football Ground
London City Airport
Thames Barrier
300 feet
HOW IT WORKS
Rocker beams
Gate arm
Steel-clad shell
Hydraulic system
River bed
Sill foundation
Open position
GATE
Closed position
Underspill position
Source: BBC Graphic News



http://www.casa.ucl.ac.uk/movies-weblog/GoogleEarth.mov

Flooding from our 3D Virtual London Model





Shifts in Traffic Accessibility if all Bridges across the Thames are Inoperable as far West as Hammersmith

Medium Term: new transport infrastructure projects with large scale regional repercussions

Road, v=3.5M, e=8.4M

Street/Road Network

Bus, Ferry, v=0.29M, e=0.42M

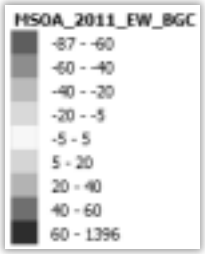
Bus/Ferry

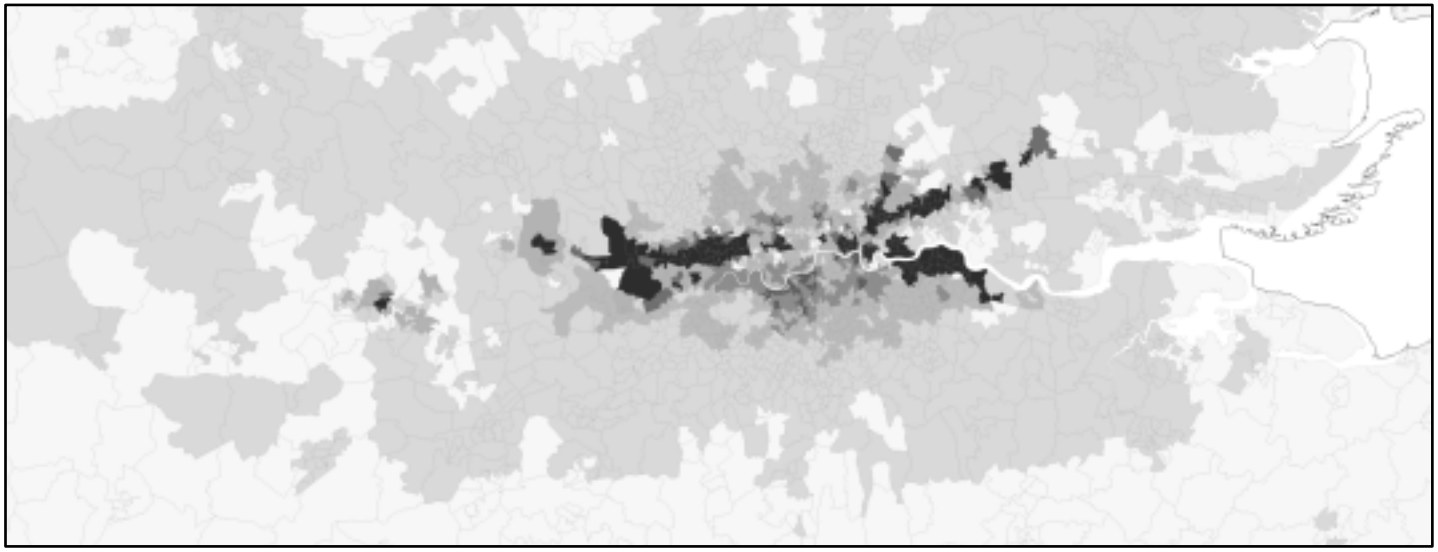
Rail, v=3165, e=10,269

Rail

Crossrail

Reading, Heathrow, Shenfield, Abbey Wood





High Speed 2

Number of improved trips (n_i>685)

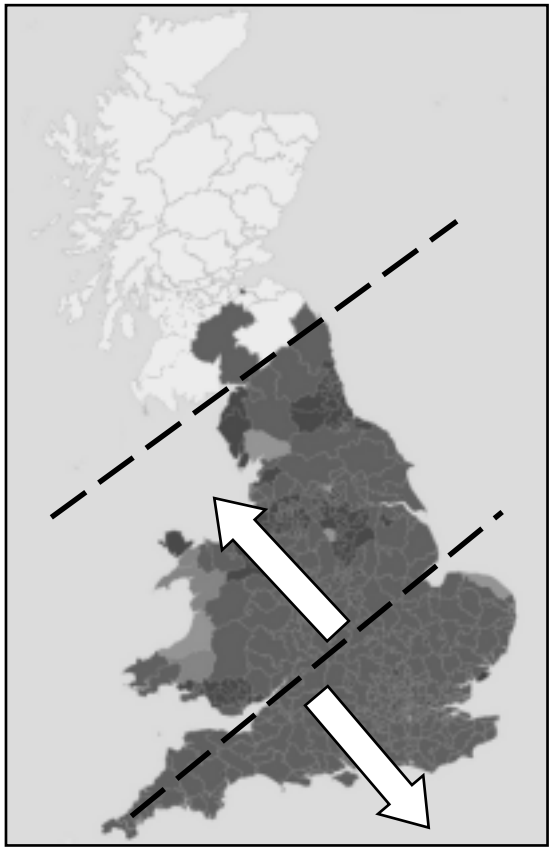
Very Long Term with Very Short Term Consequences: political upheaval and fracturing of the consensus.

Breaking Up Britain: Fracturing Britain: Defining Nations, Regions and Cities

- Ok, let me proceed by seeing how resilient our nations regions and cities are in terms of their connectivity and we will begin by decomposing this connectivity to get some understanding of how we can define spatial units that are robust
- But first I am going to show you something about Britain and Cities from last years regional divisions pertaining to our general election
- We were very struck by these divisions

2010 .....

2015 ..... *where*



Conservatives

Labour

Scot Nationalists

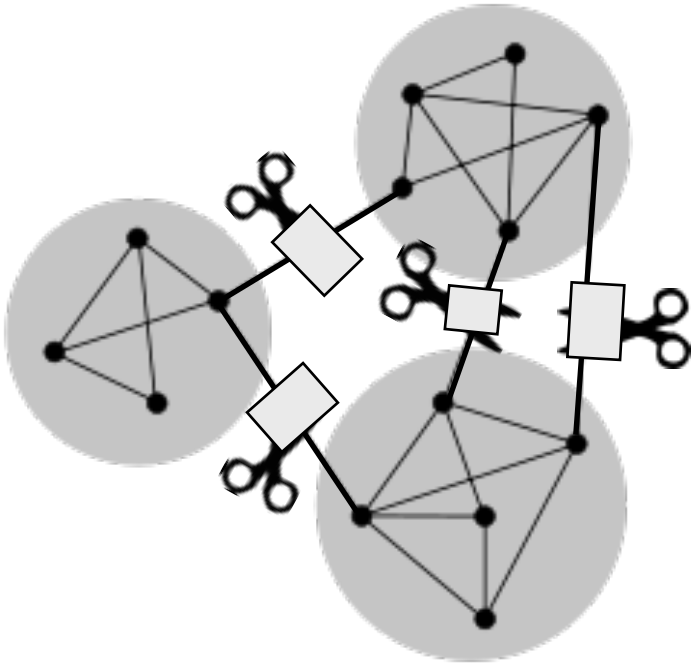
Liberal

Plaid Cymru

UKIP

I need to update you with recent events when we British voted to leave the EU.
Let me show you the map of who voted to leave the EU and who voted to stay. I will let you draw your own conclusions but fracturing of the kind I have been showing is key and so is the core-city-suburb-country difference

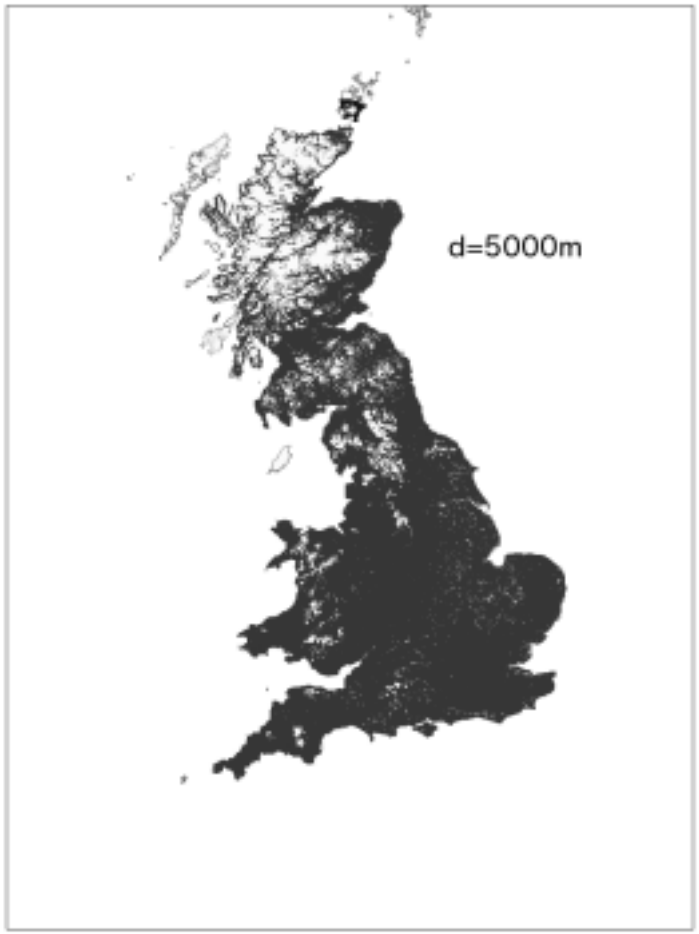
So how do we fracture Britain to predict its nations, regions and cities?
Imagine the network of streets and roads which covers these entire islands. Let us cut the longest links – those that are greater than a distance threshold – so that we partition the network into clusters, and we keep on doing this …. by tightening the threshold, thus building the hierarchy top down



Let us make it a little more relaxed and look at the key stages – the essential issue from the election and what people vote is that *Britain breaks up into its historical cultural pieces*.

We have done this for Europe and America – we are working on its for neighbourhoods

Its all about networks



Generalising These Experiences and Ideas

How relevant is all this for all cities – clear differences – we are currently looking at

- transportation and segregation in Sao Paulo and London;
- phone traffic in Senegal so we can figure out how the city works;
- work on complex adaptive systems – coupled human and natural systems in Galapagos where the population pressures are enormous.

There are very important differences we know but one factor that is very strong in all this sort of thinking is the idea of networks and physical networks are relatively easy to measure – the challenges arise when we need to look at flows and networks that are not so visible such as those which are being built by smart city technologies and new IT.

Thanks

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