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University College Dublin

Smart Cities & Big Data

How We Can Make Cities More Resilient

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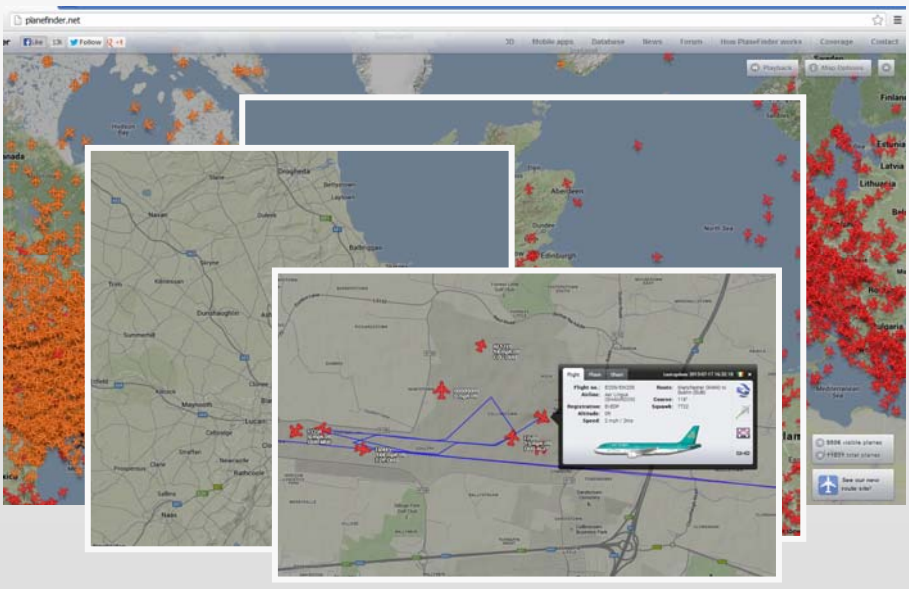
http://www.spatialcomplexity.info/
http://www.casa.ucl.ac.uk/

Centre for Advanced Spatial Analysis

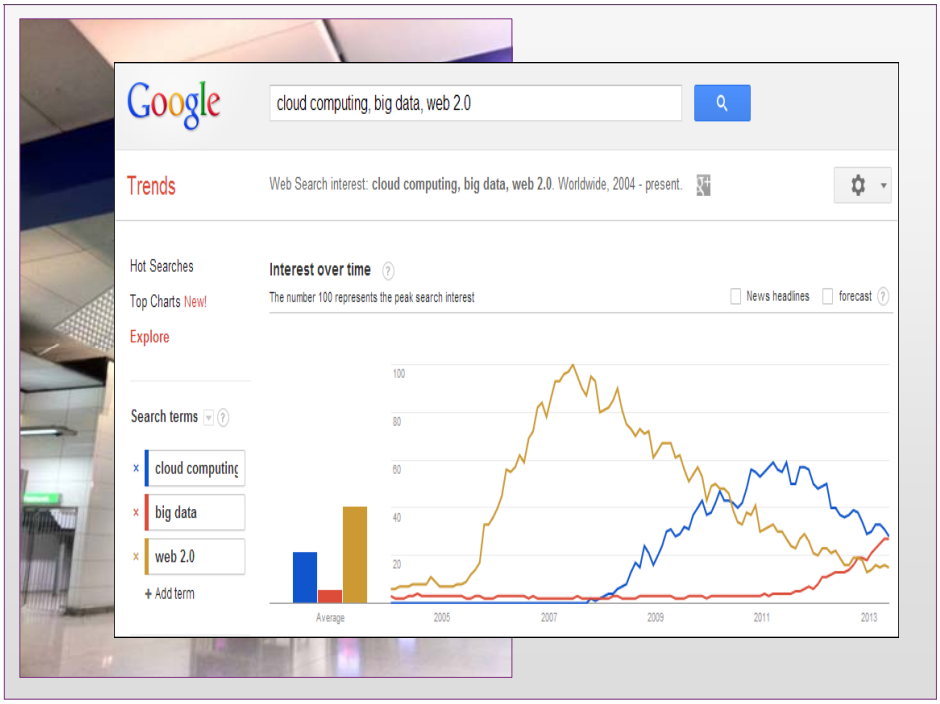
UCL

http://www.spatialcomplexity.info/files/2013/07/BATTY-AESOP-ACSP-2013.pdf

http://www.simulacra.info/



http://planefinder.net/



Key Themes

- *Changes: Big Data, Short Times, Fine Spatial Scales: The Next 5 Minutes or the Next 5 Years?*
- *How Do We Articulate Resilience in Urban Systems: Complexity, Redundancy, Robustness yet Fragility*
- The London Oyster Card Data Set
- Simpler Systems: Public Bikes as Exemplar
- Long & Short Term Flooding: Tyndall Cities Project
- Big Disruptions in Infrastructure: Olympics,Cross Rail
- Regional Breakdown: Phase Transitions
- Attempting a Synthesis: What Next for Planning?

Changes: Big Data, Short Times, Fine Spatial Scales: The Next 5 Minutes or the Next 5 Years?

Big data is distorting or at least changing our attention span from longer to shorter time periods in which intervention takes place

This is because big data is largely but not exclusively based on massive volumes – terabytes – over very short time spans – seconds – at very precise spatial scales – centimetres or less

The focus thus turns to issues such as disruption of systems for individuals over 5 minutes to 1 hour to 1 day rather than change for aggregate groups of populations from 1 year to 5 years to 50 years.

To an extent there is a general shift from equity to efficiency.

Of course big data is also being streamed incessantly without any potential end limit although systems will inevitably change and there is no guarantee that big data will tell us about change on any and every time scale.

Big data can also be traditionally collected data by manual means and a good working definition is anything that will not fit into an Excel spreadsheet – 4.56 million individual records – the population of Ireland is big data and it might be collected from many sources none of which are streamed in real time.

Big data is also as unreliable as small data and perhaps more so and I will tell you of some problems in it as we go along.

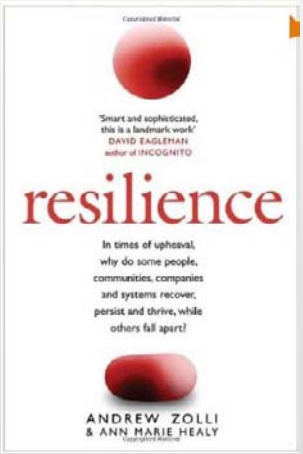
How Do We Articulate Resilience in Urban Systems: Complexity, Redundancy, Robust Yet Fragile

If our attention is shifted to the short term, the focus changes from issues of equity in aggregate populations to issues of efficiency in individual behaviours. The focus also shifts from ideal states to dynamic change.

It shifts to how systems are disrupted, and one of the very obvious ways is that the links between the parts that compose a system get fractured or broken in some way. In short, the very definition of a system as a set of interacting parts contains within it the seeds of its own destruction.

Networks and their robustness to fracture is of the essence.

Now in the popular science book *Resilience* written by Zolli and Healy last year, 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 same logics apply to everything from the financial crisis to the spread of epidemics.

My recent favourite example is the M25 orbital road which has not had one day free of closure in the last 3 years. Even more recently failures in the UK NHS due to systematic management breakdowns, not resources per se.

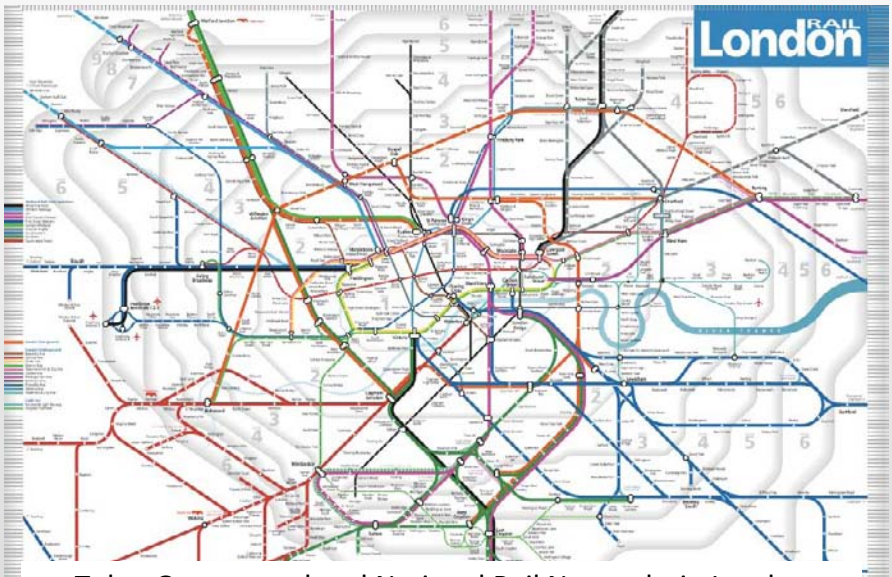
An excellent example of all of this is the forest fire and let me tell you how such a fire works. Imagine a grid of trees widely spaced – a tree catches fire due to a lightening strike but burns out. As the trees get closer together, those adjacent to one another burn but only when 59% of the area of the forest is full of trees, does the entire forest burn down. This is the percolation limit – absolutely critical for breakdown.

The London Oyster Card Data Set

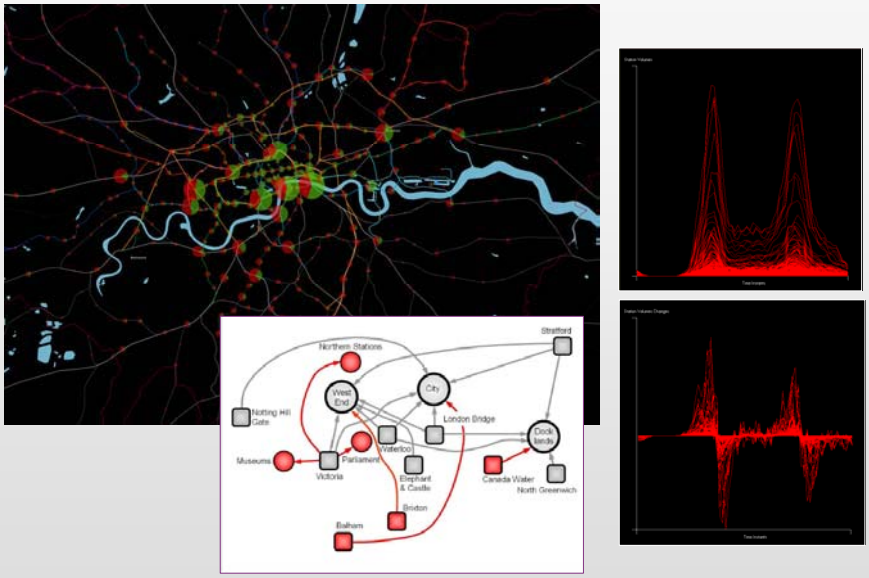
Ok let me begin to illustrate these ideas with some examples. which involve big data and networks. Our Oyster card data set involves all tap in and tap outs by unique ID number with location and time for every person over a 6 month period

7 million a day, 40 million a week, 160 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.

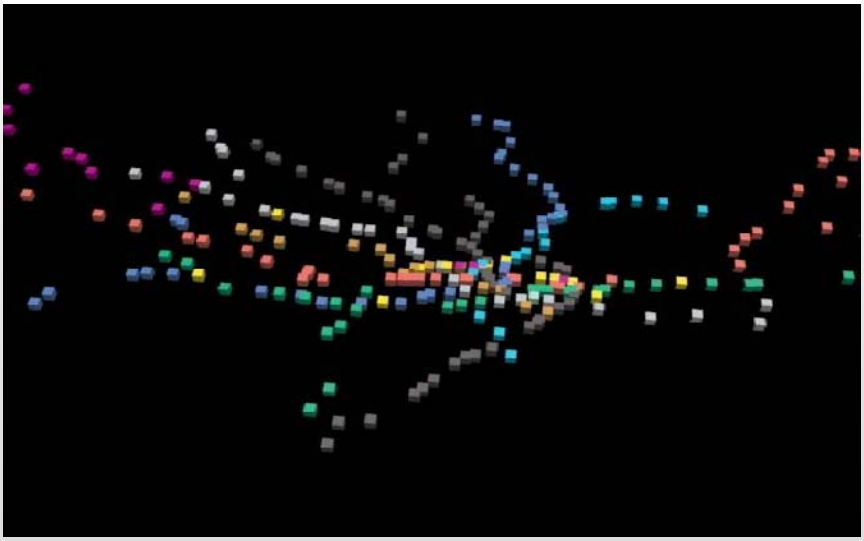


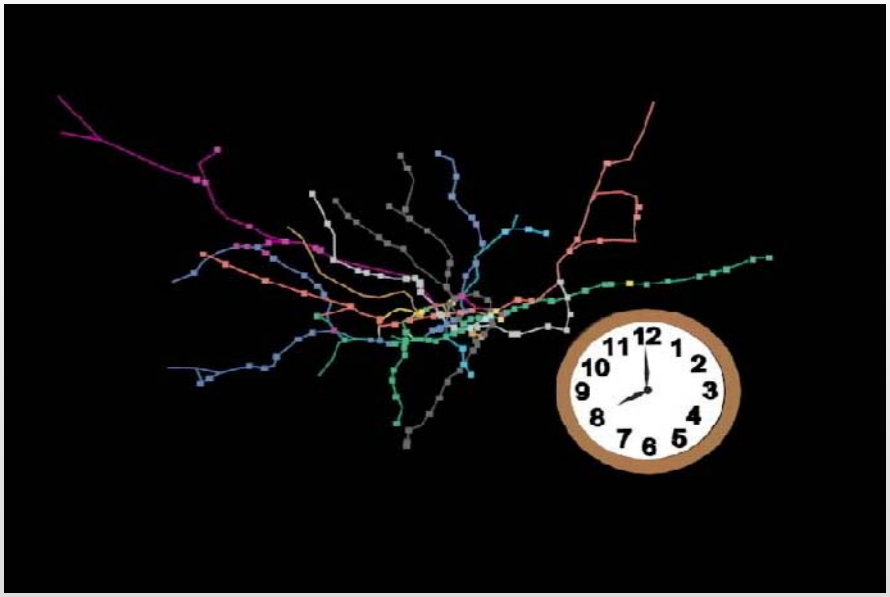
Tube, Overground and National Rail Networks in London where Oyster cards can be used



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?



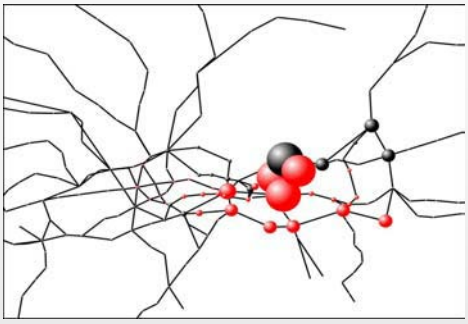


The effect of a bus strike

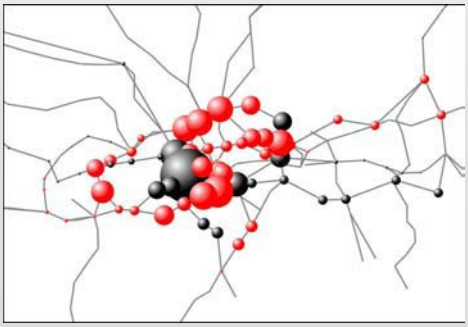
Tuesday 22nd May 2012, 09:00

Wednesday 23rd May 2012, 09:00

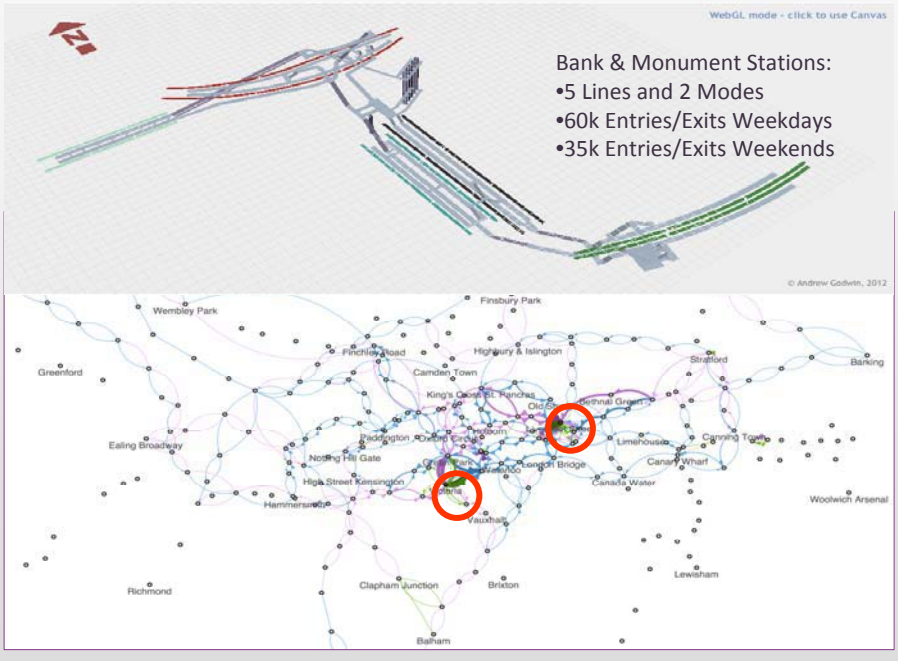
The left image shows the effect of the bus strike on 22nd May 2012, while the image on the right shows a normal day.



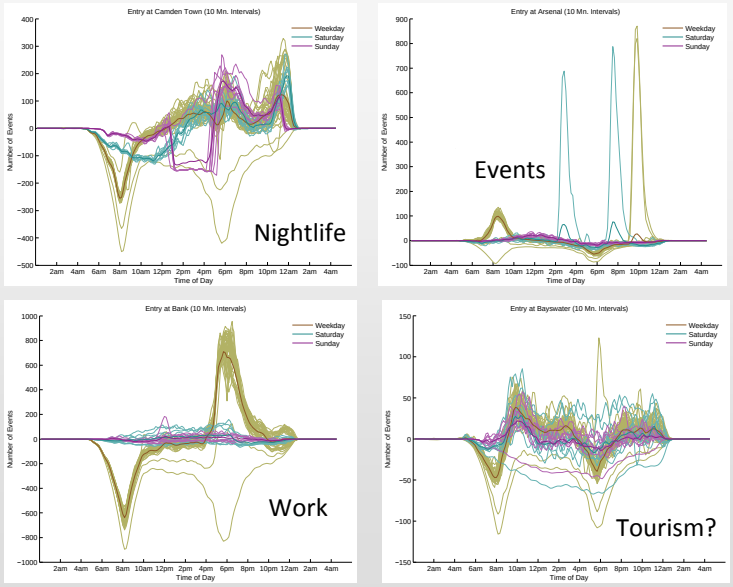
Disruption caused by closing Liverpool Street in terms of the graph of the tube network



Closing Green Park – shifts in betweenness centrality



Particular Events: Weekdays, Saturdays and Sundays



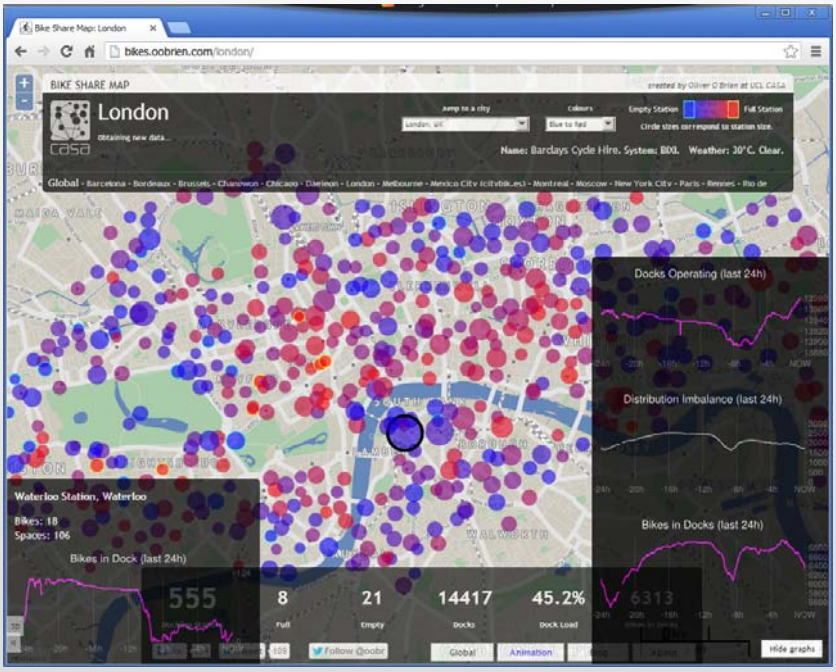
Simpler Systems: Public Bike as Exemplars

World-wide case study from Ollie O'Brien:

100 cities, 3 years of data
- Docking station status
- Journey records

Looking at cultural behaviour
- Each docking station shown by a circle
  - Blue = empty, Purple = ~50% full, Red = full
- Normally two graphs
  - Weekday (normally Wednesday)
  - Weekend (normally Saturday)

Live versions at http://bikes.oobrien.com/
Let us look at London

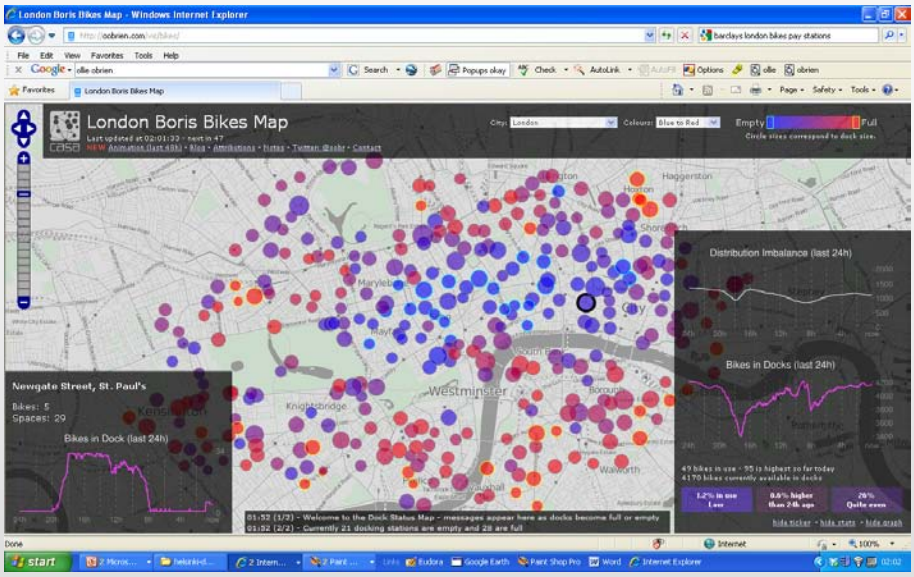


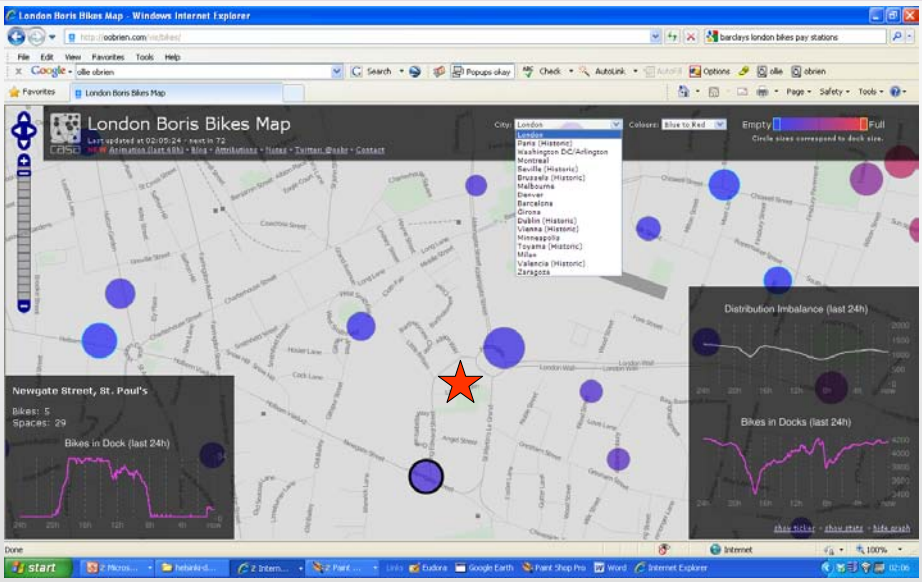
The Barclays Cycle Hire London Project

BCH commenced operations in July 2010 with **5,000 bicycles** and *315 docking stations* distributed across the City of London and parts of eight London boroughs.[10] The coverage zone spans approximately 17 square miles (44 km2), roughly matching the Zone 1 Travelcard area.

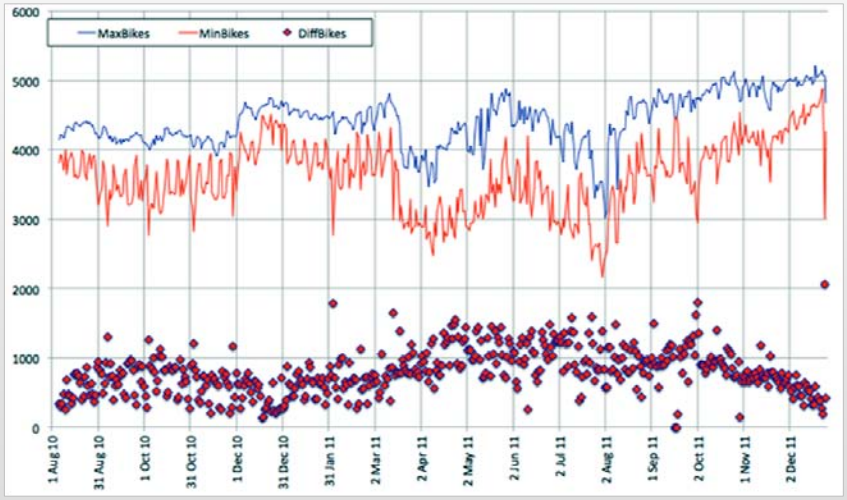
Currently there are some **8,000 'Boris Bikes'** and *570 docking stations* in the BCH scheme, which has been used for over *19 million journeys* to date

City	Official Name	Installed	System	# of Bikes
London	Barclays Cycle Hire	July 2010	Bixi	4,300
Barcelona	Bicing	March 2007	Bikemi	4,200
Milan	Bikemi	December 2008	Bicing	1,100
Saragossa	Bizi	May 2008	Bicing	800
Girona	Girocleta	September 2009	TNT	100
Washington DC and Arlington	Capital Bikeshare	September 2010	Bixi	650
Montreal	Bixi	May 2009	Bixi	4,200
Minneapolis	Nice Ride	June 2010	Bixi	600
Denver	B-cycle	April 2010	B-cycle	350
Melbourne	Bike Share	June 2010	Bixi	400

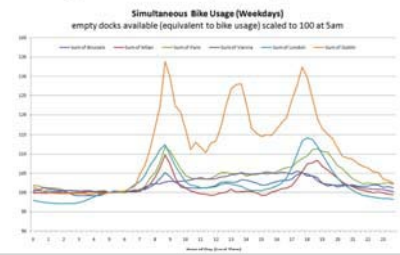




As yet no records of demand from people logging on, so no management capabilities, but could happen probably from an App based software but maybe from the server

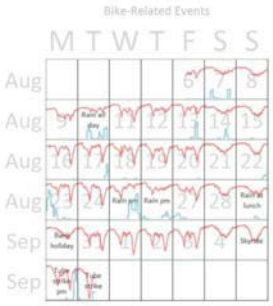


Weekday Use – 1. Europe ex-Spain

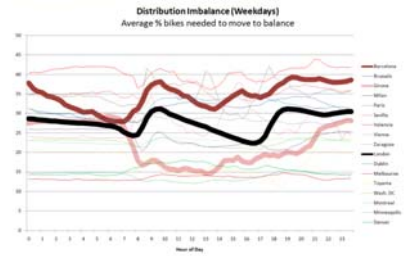


More Analysis

- **London**
- Graph shows number of bikes available to hire
- Effect of rain
  - Using the CASA weather station
- Effect of the tube strikes

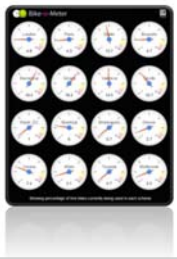


Redistribution Effectiveness

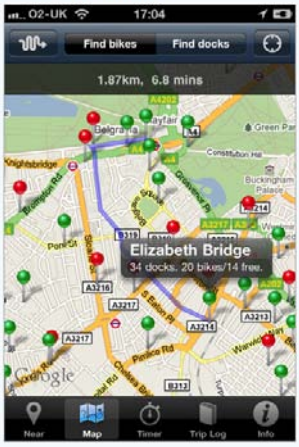


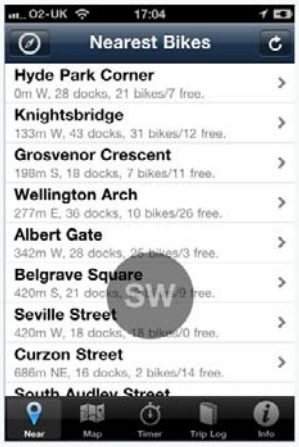
Bike-o-Meter
casa.ucl.ac.uk/bom

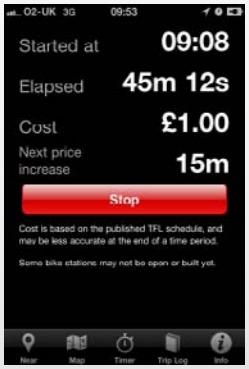
- Tweet-o-Meter for bikes
  - Steven Gray (@frogo)
  - Using Google Gauges
- See the real life Tweet-o-Meters at the new British Library "Growing Knowledge" exhibition
  - Should be easy to hack to show the Bike-o-Meters instead ☺



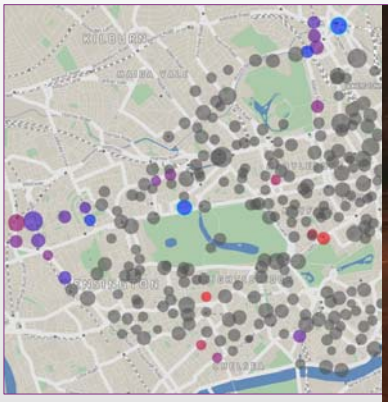
iPhone Screenshots





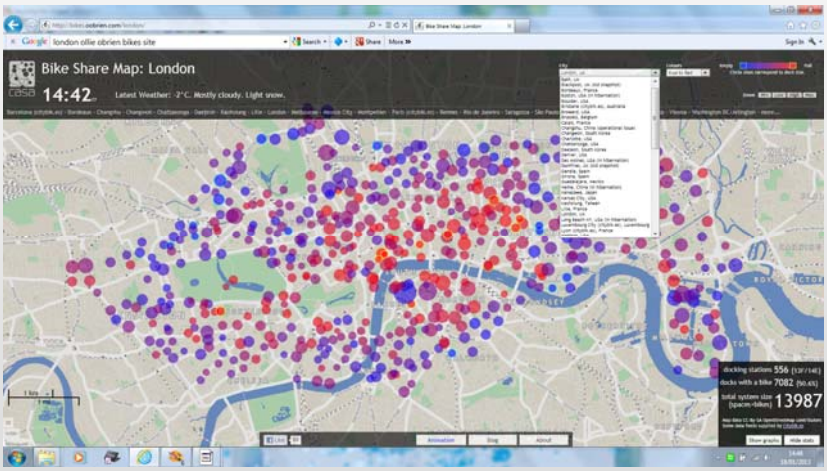


http://oobrien.com/vis/bikes/

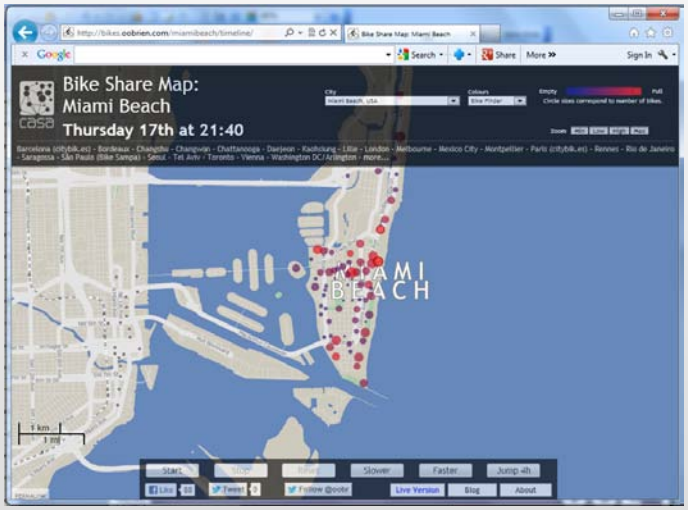


The Website: Real Time Visualisation of Origins and Destinations Activity

http://bikes.oobrien.com/london/



Your can play back the last couple of days from the animator for many of the cities where the data is captured online



Initial Analyses

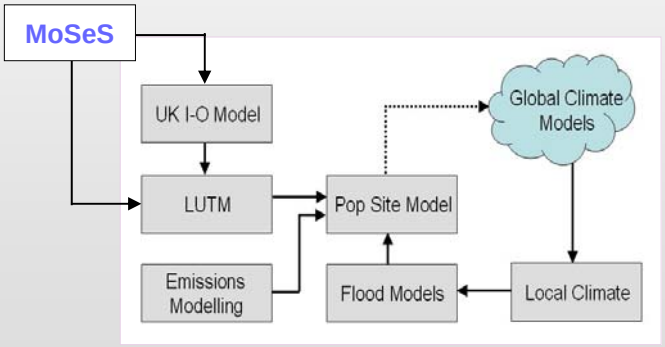
Flows – Origins and Destinations

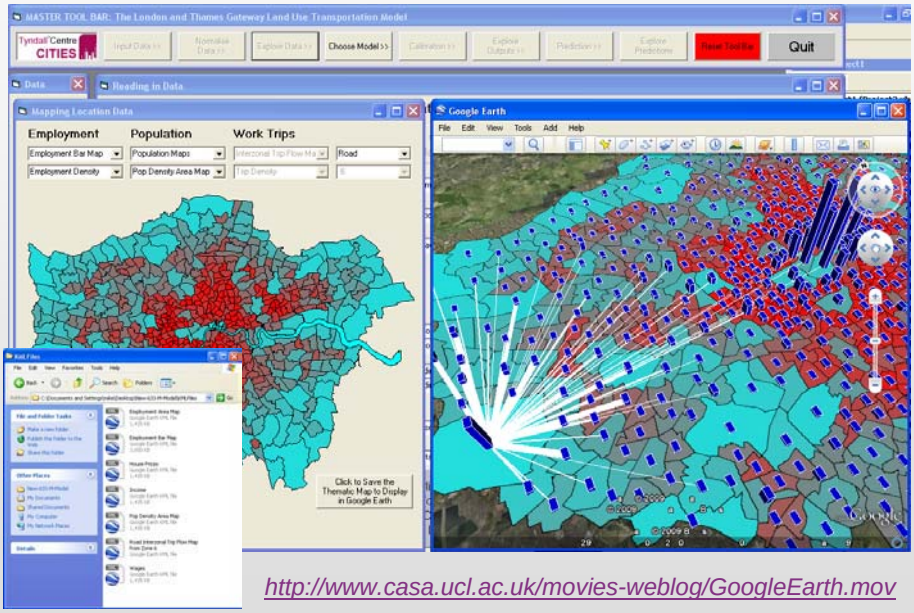
Thre are quite a few visualisations on Vimeo which have been developed by James Cheshire and Martin Austwick where they have used shortest routes methods to figure out bike paths

http://vimeo.com/19982736 **And one from Jo Wood at City University** http://vimeo.com/33712288

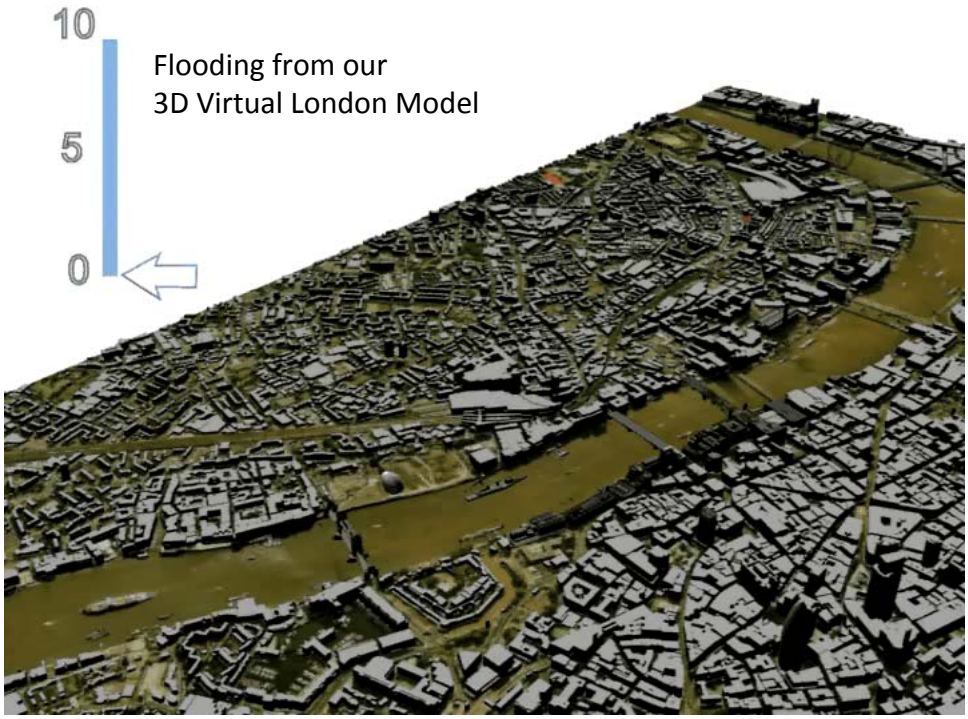
Long & Short Term Flooding: The Tyndall Cities Project

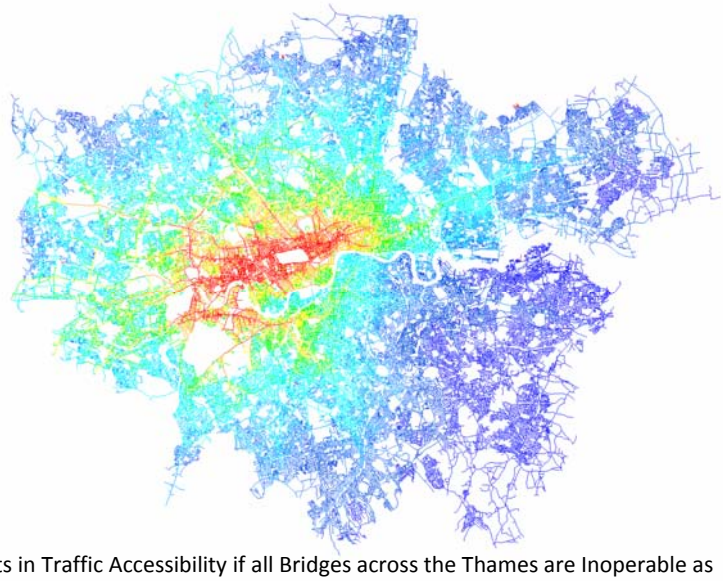
We have been involved in a large consortium project led by Newcastle Civ Eng to look at an integrated assessment of climate change in Greater London





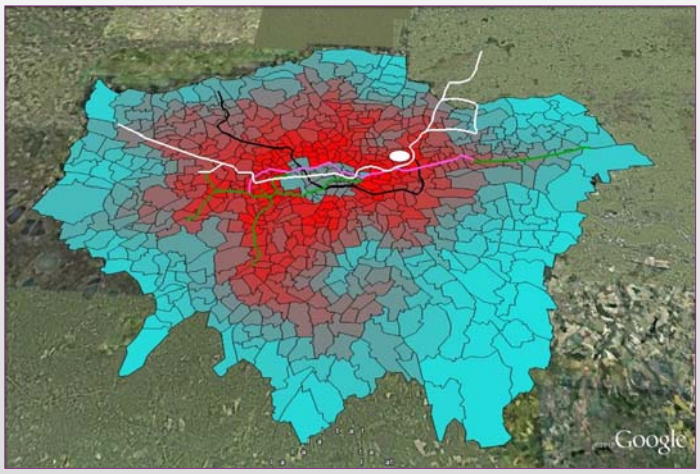
http://www.casa.ucl.ac.uk/movies-weblog/GoogleEarth.mov



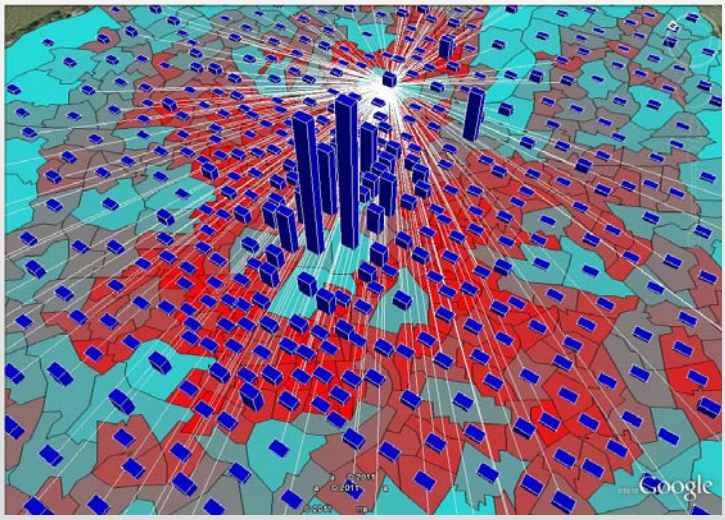


Shifts in Traffic Accessibility if all Bridges across the Thames are Inoperable as far West as Hammersmith

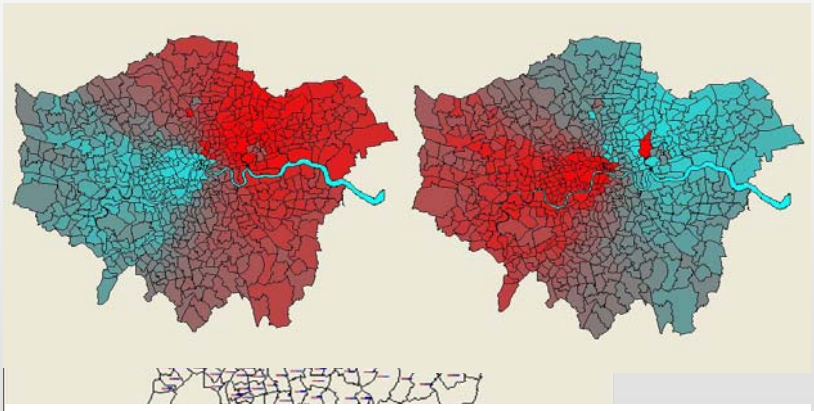
Big Disruptions/Additions in Infrastructure: The Olympics games Regeneration of East London and Cross Rail



The Impact of Additional Employment and Population at the Olympic Games Site in East London

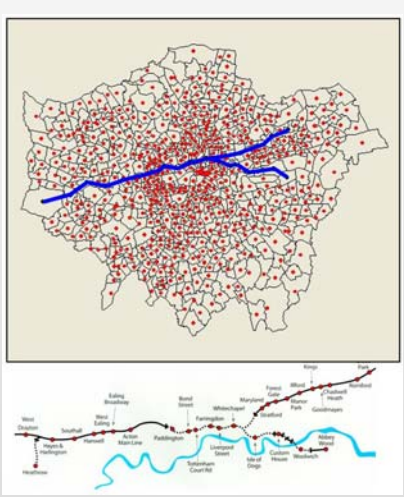


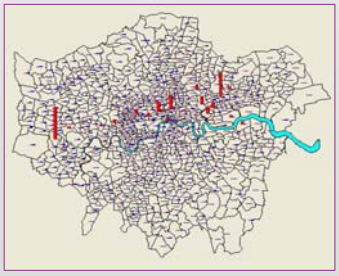
Absolute Gains in Population (left) in East London but Relative% Gains in Population in West London (right)



M. Batty (2012) Urban Regeneration as Self-Organisation, **Architectural Design**, **215**, 54-59

Cross Rail: The High Speed Rail Line from Maidenhead to Stratford – 30 trains an hour each way





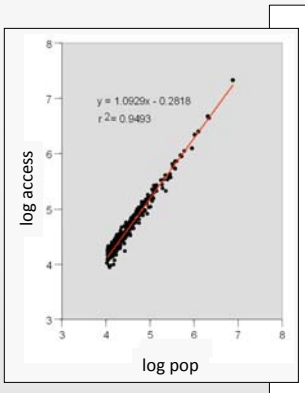
Regional Breakdown: Phase Transitions

My last example shifts scale massively to the entire country. We are working on a problem essentially in the regional economic geography of the UK – or at least England, Wales and Scotland examining how prosperous cities are with scale.

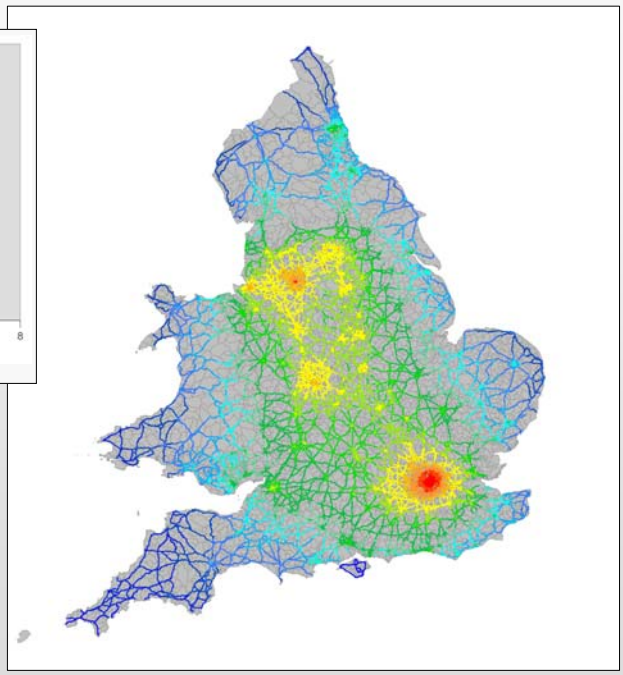
This is called allometry of city sizes – the idea is that as cities grow they generate economies of scale and to cut a long story short, their per capita income grows with size. This is called superlinearity – in short their metabolism get faster with size – the pace of life gets faster, congestion gets greater and crime gets greater per capita as does income, inventiveness and so on

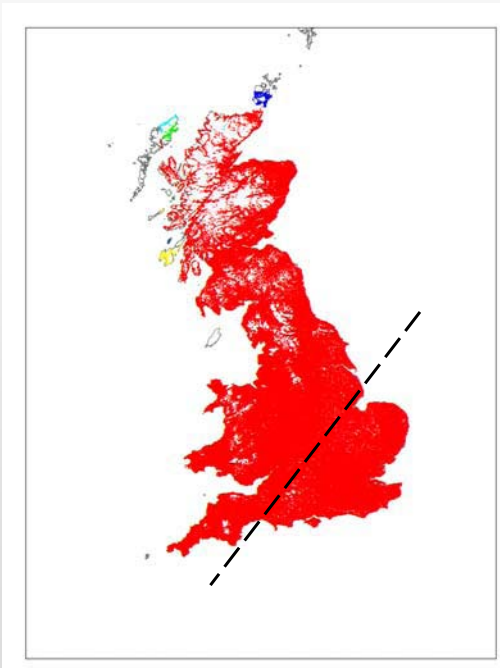
I cant go into this in any detailed but to do this we need to construct cities from the ground up – to define them – the work done in the US for MSAs indicates that for every doubling of city size, income more than doubles going up by 215% or so.

In the UK we have not found this – incomes do not go up superlinearly but linearly and this we believe is due to many factors – it may well be that the UK urban system is much more integrated than the US – more global and it may be that policy, historical path dependence of how the country has developed and so on is key – we don't know but we need to define proper defintions of cities and this we are using percolation theory to do this – let me give you a sense of how we can break up the regional system from the UK network



A Theory of City Size, **Science**, 21 June 2013: Vol. 340, 1418-1419





What we do is we decrease the distance threshold for places to connect with one another systematically, starting from any integrated system – where we show the top ten clusters in terms of size

This reveals the splits in the system eventually giving us cities

Attempting a Synthesis: What Next for Planning?

Ok a longish talk I know but basically my point is that big data is changing our focus – and in some senses planning needs to respond –

The danger is that we shift too radically – big data gives is the opportunity to develop new more focussed tools for dealing with short terms changes but this does not negate long term change, our traditional focus

In some senses, this enriches our ability to understand, manage and intervene.

There is also a warning – we need to embrace these new technologies before then embrace us and work with many groups of people – other disciplines that are moving in on these domains

I could say a lot more but I won't – just to give you my coordinates and remind you that this power point as a pdf is on one of our blogs at

http://www.spatialcomplexity.info/files/2013/07/BATTY-AESOP-ACSP-2013.pdf

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